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ABSTRACT

To facilitate the development of self-instructional programs for the SAGE Track Monitor and Intercept Director, job characteristics were outlined in behavioral terms, including: job knowledge, decision-making, problem-solving, perception, position-motor, symbolic identification, and sequential. Task characteristics were related to the following program variables: form of response, type of feedback, method of cueing, size-of-step, organization of frames, and branching. Programing considerations are discussed, sample frames provided, and the results of a study comparing two programing techniques reported. (EMH)

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PRINCIPLES OF PROGRAMMING AS APPLIED TO THE DEVELOPMENT OF TWO SELF-INSTRUCTIONAL PROGRAMS FOR SAGE OPERATORS

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FOREWORD

This is one of a series of seven reports prepared by the American Institute for Research under Contract AF 19(604)-5951, Development of optimal methods of organizing and presenting SAGE operator job information in self-training equipment. The complete series is listed below, with authorship, title, and report number indicated for each document.

1. Shettel, H. H., Angell, D., Fazio, Janet L., Lindley, R. H. & Lumsdaine, A. A. Training requirements for the development of prototype self-instructional programs covering basic job knowledge for SAGE Track Monitor and Intercept Director operator positions. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-SR-246 (ESD-TN-61-52)

2. Shettel, H. H. & Lumsdaine, A. A. Principles of programming as applied to the development of two self-instructional programs for SAGE operators. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-SR-247 (AFCCDD-TN-61-27)

3. Shettel, H. H., Angell, D. & Lumsdaine, A. A. Handbook for the preparation of self-instructional materials for SAGE operators. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-SR-248 (AFCCDD-TN-61-30)

4. Shettel, H. H. & Lumsdaine, A. A. Characteristics of self-instructional devices to meet training requirements for the SAGE Track Monitor, Intercept Director, and related system-operator positions. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-SR-249 (ESD-TN-61-47)

5. Shettel, H. H. Evaluation of two prototype self-instructional programs covering basic job knowledge for SAGE Track Monitor and Intercept Director operator positions. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-SR-250 (ESD-TN-61-51)

6. Shettel, H. H. & Lindley, R. H. An experimental comparison of two types of self-instructional programs for a SAGE system paired-associate task. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-TR-251 (AFCCDD-TN-61-20)

7. Shettel, H. H., Angell, D. & Lumsdaine, A. A. FINAL REPORT (Short title) Self-instructional programs for SAGE system operators. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-FR-252 (ESD-TR-61-17)

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Members of the research staff of the American Institute for Research who made major contributions to various phases of the work done under this contract include: Arthur A. Lumsdaine (Principal Investigator), Harris H. Shettel, David Angell, Janet Fazio, and Richard Lindley.

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ABSTRACT

The essential characteristics of the Track Monitor and Intercept Director tasks, for which self-instructional programs were developed, are described in behavioral terms. These characteristics were identified as including the following kinds of behaviors and skills: job knowledge (academic), decision-making, problem-solving, perceptual, positional-motor, symbol identification, and sequential. Emphasis is placed on these task characteristics only in so far as they had implications for the programming methodology used. The rationale developed for relating this programming methodology to the identified task characteristics is discussed in detail in terms of the following specific programming variables: form of response, type of feedback, method of cueing, size of step, organization of frames, and branching. Selected frames from the Track Monitor and Intercept Director programs are shown and discussed as examples of the application of each of these variables to various task characteristics. In addition, the organizational structure, the distribution of written (and other) responses, and the use of branching sequences is discussed for each program.

A study done to compare the effectiveness of two methods (i.e., flash card techniques and continuous-discourse self-instructional programs) of presenting discrete-item, paired-associate material (e.g., the phonetic alphabet) is briefly reported. The way in which the results of this study, which supported the use of the flash card techniques, were applied to the development of the two programs, is discussed.

Also presented are implications derived from the development and use of these programs for improved programming techniques as applied to SAGE and related L-system tasks.

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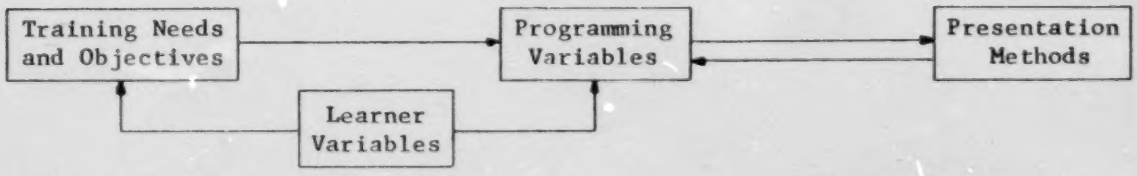
I. INTRODUCTION

Those who write self-instructional programs must decide on the method or methods of programming they feel will most adequately teach the subject matter. These variations in approach can be called "programming variables," and are the main concern of this report. In addition, the programmer is faced with a number of decisions relating to the coverage and organization of the subject matter, these in turn being derived from an analysis of the task and definition of program objectives. These can be called "subject matter variables," or, as finally arrived at, "training needs." A detailed discussion of the task analyses and training requirements as developed for the Intercept Director (IND) and Track Monitor (TM) tasks is found in another report in this series (ESD-TN-61-52).[1]

These two sets of variables are influenced by a third factor which must be considered in any practical discussion of programming techniques. This third factor may be called "program implementation" and refers to the method which is used to present the program to the trainee. A detailed discussion of the equipment used in the Track Monitor and Intercept Director self-instructional programs and its relation to programming variables is contained in ESD-TN-61-47.

Affecting both training needs and programming techniques, the learner himself introduces a fourth set of variables.

These interactions are shown in the following diagram:



[1] This report, along with the other reports prepared in connection with the work done under this contract, is listed in the Foreword.

In this report, emphasis will be given to the area of programming variables as they interact with characteristics of each task, defined in behavioral terms. References to learner variables and presentation methods will also be brought into the discussion as they relate directly to problems of programming methodology.

Since the self-instructional programs discussed in this report cover the Track Monitor and Intercept Director tasks, a short general description of each task is appropriate for the reader who may not already be familiar with them.

The Track Monitor's task is, as the name implies, essentially a surveillance one. The Track Monitor (TM) must scan a display which contains large amounts of symbolic material (computerized data), looking for "aircraft" whose track symbology shows an existing or potentially dangerous condition. There are five or six reasons why track symbology may be of poor quality. The TM must diagnose the problem and then take one of five actions available to him to solve the problem. (In effect, by taking action the TM "tells" the computer what to do to solve the problem. He does this by making appropriate button and switch insertions on his console unit.) These problems can occur in any order, with any frequency, and at any place on the display. They vary in importance so that a priority system must be applied when more than one problem arises at a time (which frequently happens). Thus this task is characterized by random searching for problems (surveillance), diagnoses of problems, the taking of the proper corrective action, with then a return to searching behavior. Criterion performance might be summarized as "keep your display as free of problem tracks as possible."

The Intercept Director (IND) has quite a different sort of task. It is his responsibility to direct fighter aircraft against target aircraft so that the former is in a position to destroy the latter and to subsequently return the fighter aircraft safely to an airbase. Once a mission is assigned to an IND, he directs the pilot toward his target by voice radio, using as guidance symbolic information (computerized data) he receives on his console display. He can take actions by making button and switch insertions which will inform the computer of necessary mission changes. The computer performs all the calculations

relating to optimal tactics, target heading and speed, etc., and displays them back to the IND on his console. Much of this information must, in turn, be relayed to the pilot. In effect, the IND is the responsible individual for the success of the mission and the safety of the pilot. INDs may (and frequently do) handle more than one mission at a time.

II. TASK CHARACTERISTICS

Task characteristics are considered in the context of skill and behavioral variables that have implications for programming techniques. A specific subject area is important here only in so far as it is representative of a class of behaviors or skills needed by the trainee in order to learn and perform the task.

A number of common task elements appeared as a result of the analyses made for both the Track Monitor and Intercept Director positions. The elements were identified as part of basic job knowledge for each task and are as follows:

1 -- A general understanding of what SAGE is, how the specific task being covered (TM or IND) fits into SAGE, and how it interacts with related SAGE tasks.

2 -- Knowledge of all the symbology (track and digital) normally used in the performance of the task.

3 -- Knowledge of the use of all buttons and switches on the console equipment (including the Auxiliary Console for the IND) that are normally used in the performance of the task.

4 -- Ability to read and interpret a flashing situation display.

5 -- Ability to perform all basic actions required by the task, including the knowledge of <u>when</u> to perform them and <u>why</u> they should be taken.

That each of these areas must be covered in varying degrees in their respective programs is not important here. As already noted, this subject is dealt with in another report (ESD-TN-61-52). What is important is to relate these job knowledge and skill areas to more general categories of behaviors and skills.

This must be done so that programming variables can be selected which relate indirectly to subject matter areas through the behaviors and skills of which they form a part. In this way, a general topology of programming can be developed, since otherwise every subject matter area will be a unique programming problem. An analysis of the above subject matter areas reveals that they involve the following kinds of behaviors and skills:

- Job knowledge (academic) skills
- Decision-making skills
- Problem-solving skills
- Perceptual skills
- Positional-motor skills
- Symbol identification skills
- Sequential skills

Each of these areas will be discussed as an introduction to the more detailed analysis of programming methodology. In each case they will be related to the job skills (subject matter areas) listed above.

Job knowledge (academic) skills

The terms job knowledge or academic skills, in this context, refer to the kind of information that is related to a task but does not enter directly into the performance of that task. Two types of academic skills can be identified, indirect and direct. To take a simple example of the former, it could be maintained that a SAGE operator should know that "SAGE" stands for Semi-Automatic Ground Environment. However, at no time in the performance of his duties could it be claimed that such knowledge is required in order to carry out those duties successfully.

How much of this type of material to include in a program is largely a judgmental matter. At one extreme is the philosophy of training represented by those who would include considerable indirect academic material (covering

such areas, for example, as computer programming logic), as a necessary part of a training program for SAGE operators. At the other extreme are those who would rigorously exclude everything from the program except that which is directly related to the criterion behavior. Thus one might argue that if the knowledge that "SAGE" stands for Semi-Automatic Ground Environment does not enter into the performance of the job, then it would better be left out of the program. According to this view teaching this behavior would, at best, constitute irrelevant information, wasting the time of the programmer and the student, and, at worst, would interfere with the learning of relevant job-related behaviors.

Between these extremes, but reflecting more the latter approach, lies the area chosen in the present instance. To some extent this is a matter of giving a program "face validity" to those who will use it. To a greater extent, however, it is a matter of theoretical orientation. It is indeed the case that a SAGE operator works in an environment in which certain limited information beyond that specifically required to perform the job appears helpful in order for him to function in that environment. A specific analysis of precisely what this information should include was not made, but was derived from experience gained in interviewing and observing operators on the job. Approximately the first 35 frames in each program teach indirect academic skills, covering general topics, e.g., relationship between the Weapons Branch and Air Surveillance Branch, kinds of data inputs into a Direction Center, etc. A few other frames of this type can be identified, "salted" throughout each program. This type of orientation material is a legitimate part of most training programs and it is not believed that such material should be omitted when these programs are self-instructional.

There is another kind of academic subject matter (referred to earlier as "direct") that has a closer, but subtle, relationship to performance on the job. It is characterized as being essentially propaedeutic to job performance. It is the type of material that one gets only from an extrapolation of all elements that contribute to job performance, but that are not revealed by simply collecting task elements. An analysis of the Intercept Director task, for example, does not directly reveal that he should understand the communication and information net composed of the pilot of an aircraft, the computer, and the Intercept Director

himself. The IND "uses" this information (indeed the job revolves around this concept) but only in the context of many specific actions. Interviews with INDs as to what is important to know do not reveal this type of information. Yet, it makes it considerably more efficient in terms of training INDs if this interaction of equipment and personnel is explained early and specifically, rather than assuming that this relationship will evolve from individual pieces of knowledge.

Differences exist among program writers as to the most appropriate method of handling this type of direct job knowledge. One approach, identified earlier as the more extreme approach, would "teach" this type of material only in the context of specific actions. It may well not be identified as a separate area of instruction at all but would simply evolve out of the material which teaches specific job behaviors. In the present instance, the inclusion of this type of propaedeutic material early in the program as separate, identifiable units of instruction was felt to be the most effective manner of building job knowledges and skills on a prior understanding of job connected relationships and concepts.

While both programs contain academic skill material, there was more occasion to use it in the IND program than the TM program. The IND task was more complex and required the teaching of general principles and relationships to connect its various subtasks and routines.

Decision-making skills

For purposes of this discussion, decision-making skills will be defined in the context of the TM and IND positions as only that behavior which has probabilistic inputs and probabilistic outputs. Thus, the decision of the IND to return a fighter to its home base because it does not have sufficient fuel reserves to complete the mission is not a behavior which would fall under this definition of decision-making but would more appropriately be called a problem-solving skill. The input data "amount of fuel" is based on accurate information supplied by the pilot. It is simply a matter of calculating the aircraft's distance to home base and fuel consumption rate in order to determine that the pilot must return to base. However, the decision of the Track Monitor to take action on one particular track before acting on some other track is based on a number of

factors, each of which enters a certain value into the final decision to take that action. A hierarchy of track problems exist which interact with each other, leading to an action which approaches to some degree the hypothetical one best possible action. The situation in each case is unique and, once the action has been taken, one can only speculate on what would have happened had some other action been taken. It is an historical fact; one cannot "replay" the same situation with other actions except on a probabilistic basis.

It is patently impossible to cover all possible permutations and combinations for decision-making acts where the number of inputs relating to the decisions are large and where the number of alternative actions (outputs) based on these decisions are large. Thus the programmer must teach the basis for taking an action (an academic or job knowledge skill) along with a representative sample of actual actions in different contexts with consequent feedback to the trainee as to the relative adequacy of his response.

Although it was originally believed that the IND position would involve more decision-making behavior than the TM position, it became apparent during the analysis of the two tasks that decision-making for the TM is more of an integral part of his task than it is for the IND. (The relative importance of the decisions made in the two tasks is not relevant here.) To put it another way, decision-making was more a part of the basic job knowledge of the TM than it was for the IND. The IND has a great deal to learn and needs to develop considerable experience before he is in a position to make the kinds of decisions which are a part of the experienced operator's task. A number of constraints and well-developed procedures, in addition to a considerable amount of automaticity in connection with the IND position, tend to restrict the number of decisions under nonstressful, single mission, more or less ideal conditions which were considered to represent basic job knowledge. A TM, on the other hand, is constantly faced with a comparatively unstructured situation from which he must extract information on which to base his next action. This is the essence of his job. Thus the TM program actually became more involved with the problem of decision-making skills than did the IND program, with consequent implications for programming techniques used in the two programs.

Problem-solving skills

The statement made in the previous section concerning the relative frequency of occurrence of decision-making skills in the TM and IND basic job knowledge programs is reversed when we consider problem-solving skills. The relationship between aircraft fuel reserves and distance to home base, cited above, is an example of problem-solving behavior. The IND has a rather large number of these kinds of problems to solve although the computer is being given the responsibility for more and more of them.

Two interesting sidelights are pertinent here. If a condition of hostility exists the simple "problem" of fuel reserves may turn into a "decision," i.e., whether to allow the mission to continue even though the pilot cannot possibly get back to base. Note how many contingencies immediately enter the picture when it is cast in a "decision" mold -- trade-off of pilot for city, likelihood that other planes or missiles can destroy target, etc. The second point is that up until the latest model change (Model 8) the IND had full responsibility for computing fuel reserves. Now, however, this will be done by the computer, a much more effective problem solver. Note, however, that the computer is not likely to be given the responsibility for making any decisions about whether the pilot should or should not actually return to his base.

The TM, as indicated, has relatively few problem-solving tasks.

Perceptual skills

It is apparent after only casual observation of the tasks that both the IND and TM require some perceptual skill in order to "read" their situation displays. The nature of the TM task requires more random searching behavior, while the IND is generally confined to a relatively limited number of tracks which fall under his control at any one time. The IND, however, must observe these tracks for longer periods and in more detail than is typical for the TM.

The decision to include training in perceptual skills in the self-instructional program for these two tasks was based on the fact that such skills play an important part in the performance of these tasks. It was clear that a program designed

to cover basic job knowledge should, in some manner, develop at least elementary skills in reading the flashing display. This, of course, had implications not only for programming methodology but for ancillary equipment needed to supplement the instructional material itself.

Positional-motor skills

Complex motor skills are not associated with either of these tasks. However, familiarity with the equipment includes the ability to locate quickly the appropriate switches and buttons so that information can be selected or appropriate actions taken in an efficient manner. The transition from the training program to the operator position would obviously be facilitated if the trainee had already become familiar with the general layout in terms of the location and manipulation of controls, etc. Thus the knowledge that a particular category switch is used in requesting certain types of information should be combined with the ability to quickly and accurately locate that particular switch. As in the case of perceptual skills, such training was considered an essential part of each task.

Symbol identification skills

In terms of sheer amount of material, a review of both the TM and IND programs revealed that a knowledge of the meaning of symbols and labels is the largest of the various skill areas. The IND must know the meaning of all the labels on his console and on the console of the Intercept Director Technician. In addition, he must know the brevity code, the phonetic alphabet, all of the symbols presented on his SID, including a large number of attention displays, and all the symbology used in the four digital displays which comprise those used most frequently by him. Even with the elimination of some seldom used symbols, the total would run well up in the hundreds. The TM position is somewhat more limited in this respect, having fewer digital displays to consider and not involving the brevity code and the variety of attention displays received by the IND. It was clear, however, that both positions would require a large amount of training in this area.

Two subclassifications of skills requiring the use of some form of symbolic behavior were identified. The essential difference between these two groups was the degree to which the symbols interacted with each other and the nature of their

association with the task in which their use was involved. As an example of a class of interrelated symbols, one could consider track symbology. A symbol indicating the merit of a track is directly related to the action which one may take on a track, is related to other symbols such as track identity, and is internally related with other track merit symbols since they form a logical progression from "good" to "fair" to "poor" and so on.

The phonetic alphabet is an example of the second class of symbols which are not internally related and do not have direct implications for actions taken. There is no reason for Bravo to follow Alpha nor is there any particular importance attached to the fact that a track may be called Mike Lima rather than Hotel Oscar. This distinction became more important as program development progressed and had implications for the type of program written for each type of symbol as described here. This is discussed in a later section of this report.

Sequential skills

These skills depend not only on the ability to perform specific actions, but also on the ability to perform them in a particular order. Knowing the meaning of all the individual switches and buttons and what action they perform individually is not the same as knowing how to take "On Command" action. These skills must be practiced in their proper order as an interrelated subtask, preferably in the context of their application in the job itself. They are best learned in conjunction with the associated positional-motor skills.

This section has identified and described the classes of behavior and skills associated with the TM and IND positions. Having "pulled them out," the program writer must "put them back" in an arrangement that will most effectively lead the trainee to a satisfactory level of criterion behavior. They remain vitally important, however, since they have direct implications for the programming techniques employed, as well as for the use of equipment (teaching machines) to present the frames of the program to the trainee or equipment which provides auxiliary program inputs.

III. PROGRAMMING VARIABLES AND THEIR APPLICATION TO TASK ELEMENTS

Before discussing the ways in which the various kinds of behaviors identified in the TM and IND positions (as described in the previous section) were related to specific programming techniques, a brief discussion of programming methodology is appropriate.

Self-instructional concepts

The term "self-instructional" immediately identifies one of the characteristics of this type of instructional material. Such programs, once they are prepared, are turned over to the students or trainees who proceed through them without additional assistance (except administrative). This, however, does not uniquely define the self-instructional concept since an ordinary textbook would fall into this category or, indeed, an instructional film. Additional characteristics generally considered as important are these:

1. Self-instructional programs break the subject matter down into small, carefully sequenced steps (or frames) and present these steps to the trainee one at a time.

2. Some form of response is required (or requested) of the trainee for each of these steps before he moves on to another step.

3. The trainee is informed in some manner of the adequacy of his response, also before proceeding to the next step.

4. The trainee advances through the program on an individual basis and at his own rate of speed.

Programs which exhibit these four conditions could properly be called self-instructional. (This is not to say that programs must exhibit all of these

characteristics to be called self-instructional nor is it meant to imply that other characteristics could not properly be called self-instructional. Those noted here, however, are the ones generally considered as central to the concept [Skinner, 1954]). However, within these broad categories many techniques are applicable and many variations of techniques possible. Questions that remain to be answered include:

1. Into how many small steps or frames should the area to be covered be broken down?

2. How should these steps be organized?

3. How is it to be insured that the trainee can make the responses called for?

4. What type of response should he make?

5. How often should he respond?

6. How will the correctness or incorrectness of his response be indicated to the trainee?

7. What happens if he fails to make the correct response?

It should be emphasized at the outset that the present state of the art in programming methodology represents a combination of experimental evidence, empirical findings, and what could variously be described as intuitive hunches or "artistic" judgments. Experimental evidence for the efficacy of any specific techniques is only beginning to accumulate, and much of it is still contradictory.

In connection with the use of empirical data to measure program effectiveness, a technique which is considered inherent to the development of self-instructional materials (although certainly applicable to the development of other kinds of instructional materials) is the tryout and revision of program segments before they are considered completed. This technique involves pre-testing program frames

with representative subjects selected from the "using" population, and subsequent revision of those frames on which incorrect responses were elicited. Tryouts can be conducted a number of times until the program is considered adequate, or until all the correct responses can be made by the trial subject(s). In this manner it is possible to produce a program from successive trial and error approximations that does indeed "teach" the material.

The approach suggested here, however, emphasizes the selection and application of programming techniques based on prior analysis of skills and behaviors, techniques which have a theoretically based reason for "working" for those particular skills and behaviors. Excessive reliance on empirical feedback tends to lead to minimally, rather than optimally, effective programs, and in most cases leads only to variations within a previously decided structure and previously selected programming techniques.

Thus, an eclectic approach to program development was taken as a basic assumption. No prior commitments to any particular technique were made beyond those noted earlier as central characteristics of the self-instructional concept. An eclectic approach, however, has its distinct disadvantages. For complex subject matter, such as SAGE operator tasks, various forms of frame construction, methods of prompting and response modes are suggested. Rather than restricting the entire program to overt written responses, for example (a decision that would only have to be made once), the approach used here required the project staff to decide for each unit of instruction and for each frame what type of response was felt to be appropriate at that point in the program, for the particular subject matter covered and for the particular behavior characterized by that subject matter. The same kind of decision had to be made with respect to all the other programming techniques available.[1] The two large remaining questions are: (1) What techniques were available, and (2) How was it decided to apply them

[1] An additional "disadvantage" of this approach to programming is the complex requirements imposed on the method used to present the program materials to the trainee. A discussion of the functional characteristics of devices which would be compatible with SAGE-type tasks, as well as a description of the device designed by the project staff specifically for use with the two SAGE programs, is contained in ESD-TN-61-47.

to the programs under discussion in the manner chosen. These questions are discussed on the following pages with samples from both programs used to illustrate the specific application of each technique.

Programming variables

Five main programming variables entered into the IND and TM programs. They are:

1. Form of response and feedback
2. Method of cueing and kind of prompts used
3. Size of step
4. Organization of frames
5. Branching

1. Form of response and feedback.

Increasing attention is being given to the type or form of response required of subjects in self-instructional programs. Closely associated with method of responding is the question of what responses the subject should make. It is axiomatic that sooner or later the subject needs to make responses which meet the objectives of the training program. However, for complex skills such as are involved with the TM and IND positions, one must begin at a much lower level and gradually build up to criterion responses. Selecting the correct "building blocks" is not an easy task. The analysis of each position as to its behavioral components and subcomponents is essential in deriving appropriate response terms. Once these analyses have been made, many of the terms are self-evident. This is true for all of the behavioral and skill areas identified earlier with the exception of academic skills and decision-making skills. The problems associated with identifying the behavioral outcomes of segments covering these areas have been dealt with in previous sections of this report. Selection of responses interacts with the way in which the instructional material is organized and thus will be referred to later in Section 4, dealing with organization of frames.

Feedback is the means by which the trainee is given information as to the

appropriateness of his response. It is considered important that each response made be followed by some form of feedback, even though the cueing for that response has been tested and is considered adequate. The programmer may know that the trainee can correctly make all of the responses required but the trainee will not know this unless he has an opportunity to compare his response with the correct one or otherwise be informed that he has performed correctly. The reinforcement thus provided by knowledge of correctness encourages the trainee to proceed through the program. It does not follow that the reinforcement value of all correctly made responses is the same. Responses which are too easy would obviously be less rewarding to the trainee than a more difficult (but nevertheless correct) response. It might even be the case that an occasional error is not too high a price to pay for including responses that are actually not sufficiently prompted for all trainees. In the latter instance, the feedback provides for the correction of the error rather than simply the confirmation of having made the correct response.

Of specific concern here is the mode of response selected for given frames or segments of frames. The following list of response modes represents those which were considered available for use in the TI and IND self-instructional programs:

1. Overt-composed (written) responses.
   a. Self-corrected. After writing his answer, trainee than discloses the correct answer for comparison and judges whether his answer was right or wrong.
   b. Matched. After writing his answer, trainee discloses several possible answers, and he then indicates which one his answer matches.

2. Covert-composed (mental) responses.
   a. Self-corrected.
   b. Matched.

   (Same as 1-a and 1-b, respectively, except that trainee

merely thinks his answer instead of writing it.)

3. Selective responses.

   a. Conventional multiple choice. Trainee chooses one of a small number of selected alternatives.

   b. Extended (universe) selection. Trainee selects proper response from the universe of all possible relevant responses; thus, in a sense he is constructing his response rather than merely recognizing it as in 3-a.

4. Pointing-selection responses.

   a. Conventional multiple choice.

   b. Extended (universe) selection.

      (Like 3-a or 3-b, except that instead of choosing from a list of symbols, words, etc., trainee in effect points to the relevant part of a pictured console or display.)

5. Manual and perceptual responses on console mock-ups. Trainee is asked to perform at his console mock-up, i.e., take certain switch and button actions and/or make an interpretation of symbols and radar data on his display scope. He is then shown the correct switch positions or is given the correct scope interpretation. Both the self-corrected and matched format can be used.

All of these methods of responding were considered applicable to the SAGE tasks and frames were prepared under the assumption that a suitable device would be available for implementing these various response modes. (A description of the devices designed for this purpose is contained in the report referred to earlier -- ESD-TN-61-47.)

In general, written responses were considered appropriate when new terms were introduced or where the form of the material being taught was essentially verbal

(Fry, 1960). This would apply primarily to the general job knowledge area, particularly as concerns the learning of console nomenclature, situation display and digital display symbology, and concepts and relationships underlying terminal job behaviors. In addition, the composed answer is useful in checking (either for program revision or program analysis) whether or not the trainee has actually made the correct response. To the extent that the writing of the response, however, is not related to the task being taught, it is not a particularly good measure of the trainee's ability to perform that task. It is, nevertheless, the only concrete method of checking the trainee's specific "frame" behavior with the devices used in these programs.

Constructed written responses usually were in the form of a single word, a letter, a symbol, or track number. A written response was compared by the subject with the correct response which was made available to him only after his response had been moved under a glass cover so that it could not be changed. If a selection of possible responses was included along with the correct response, the response mode was considered to be "composed-matched." If, on the other hand, only the correct answer was made available to the trainee, it was considered to be a simple comparison, or "composed-self-corrected." The decision to use one or the other technique was based primarily on the availability of logical alternatives for the response in question, and on the strength of the response at a particular point. The initial elicitation or two of a response may be in the composed-self-corrected format, with subsequent elicitations in the composed-matched format, where the alternatives are those most likely to occur as potentially confusable elements in the actual job-related context in which the response is to be made.

Covert responses were used where response strength was considered to be fairly highly developed and, of course, where the composition of a written response was not considered necessary or appropriate.

Covert response frames ask the subject to simply "think" of a response. The subsequent frame would reveal the correct response to him (self-corrected) or a small selection of possible answers to him (matched). This type of response

allows the subject to move through the program rapidly while still providing him with a check on the adequacy of his responses (Goldbeck & Briggs, 1960).

Multiple choice frames were considered appropriate where the writing of a response was not judged to be related to the behavior in question and where a logical selection of alternatives was available. These alternatives could be either verbal, symbolic, or pictorial with graphic pointing to relevant features of parts of equipment which was drawn on the frames. The number of answer categories could range from two up to a half a dozen or so. Particular use was made of this form of responding in the teaching of the location of parts on the console equipment or in the identification of track symbology. Such pointing responses are, of course, a form of overt responding.

In cases where a finite universe of responses was available, these could be presented to the trainee all at once.[1] He would be instructed to "think" the appropriate response and then match his covertly constructed response with one of the many alternatives presented to him. Frames of this type look similar to conventional multiple choice items. However, there is an essential difference between them; conventional multiple choice items do not present all of the possible relevant response alternatives and thus form a limited universe from which to select the appropriate response. Since the universe is limited, it has cue value and only requires the trainee to recognize the correct answer rather than to "come up" with it himself. Items of the type described here, however, provide no cue value in the alternatives presented to the trainees since they exhaust all relevant answers. Thus, in effect, the trainee is required to "compose" his response and then find the alternative that matches the one he composed. This type of response mode was particularly useful in teaching the identification of track and digital symbology.

The following frames have been selected from various parts of the two programs as examples of the various response modes referred to above and described in more detail below. Also included is a discussion of the type of feedback

[1]The two devices used in this research allowed up to either 19 or 28 answer alternatives to be used at one time.

represented by each frame. These frames do not form a self-contained unit of instruction but were selected from various parts of the IND and TM programs only to illustrate particular forms of responses and the type of feedback provided to the trainee.

1a. Overt-composed; self-corrected.

"Lock-on" occurs when the pilot locates the target on his own radar fire control equipment. The pilot reports "Judy," meaning "I am taking over the interception," when this radar [ ] with the target occurs.

---

lock-on[1]

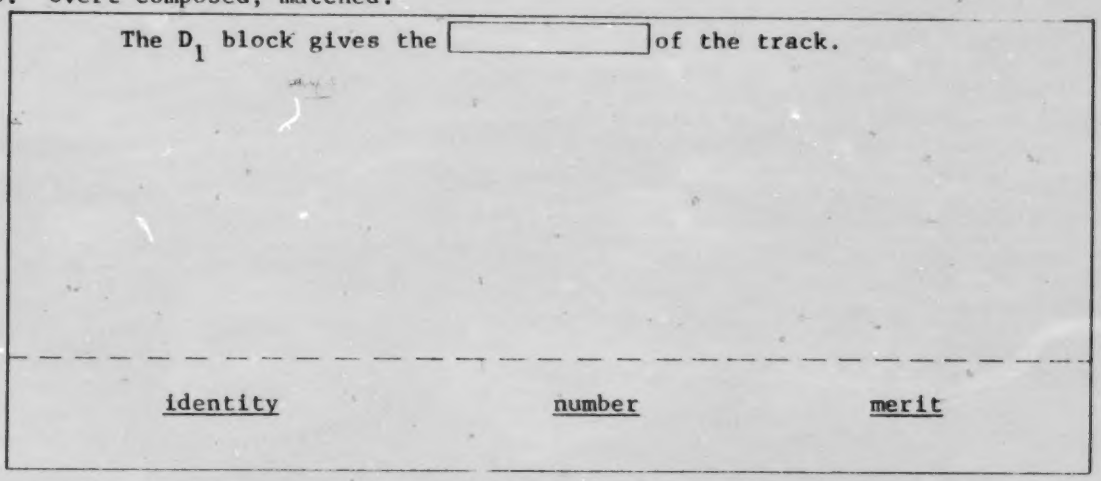
Frame 1a is an example of a written-overt response which is then self-corrected by comparing it with the correct response. (The open box was the convention used for indicating that a written response was required.) The trainee, of course, would not be able to see the correct answer (get feedback) until after he had written his response and until that written response was moved under glass so that it could not be changed. (This provision was built into the equipment and provided for cheat proof overt responding.) This is a conventional Skinner-type response.

In addition to seeing the correct answer the trainee also sees the original stimulus material (that portion of the frame above the dotted line). The inclusion of the entire frame in the feedback mechanism was considered to be important. A

[1] That portion of the frame below the dotted line on this and all subsequent frames is revealed to the trainee only after he has responded (and, for written responses, only after his answer has been moved under a glass cover).

simple right/wrong indication for the response given would be of little value to the trainee in the event he missed the response or was somewhat uncertain of it, since the original context in which the response was made would no longer be available to him. The above characteristic is true of all of the frames used in the two SAGE programs.

1b. Overt-composed; matched.



Frame 1b is another example of a written-overt response. It differs from Frame 1a in that the trainee is provided with a selection of possible alternative answers against which he matches the response he wrote. (Again the trainee does not see the alternate responses until after he has made his response and it has been moved up under glass.) An advantage of this form of responding is that the program does not simply reveal the correct answer, but requires the trainee to make a choice. This response format makes provision for a second, or third try (or more if there are more alternatives) for wrong answers since only when the right answer is selected will the program advance to the next frame.

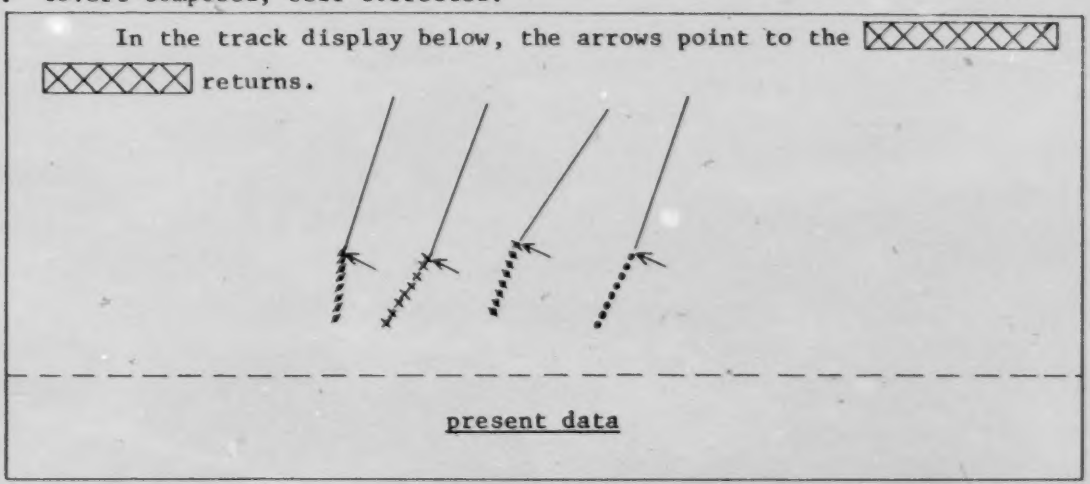
This technique is particularly valuable where discrimination must be developed between similar terms and is also an excellent way of introducing branching sequences (as described later).

It should be noted that in the event the subject writes the wrong response

he may recognize the correct response when these are revealed to him. There is nothing to prevent him from pointing to the correct response (and going on) even though he may have written the incorrect one. From the programmers point of view, this can be considered as acceptable even if not ideal, since the intent of the program is to teach correct responses and not to punish wrong responses.

When the subject has a selection of responses to choose from, he knows he has made the correct choice if the program advances to the next frame when he elects to go on. If he selects an incorrect response (and it is not a branching sequence), the feedback is "program did not advance to the next frame." He must then select one of the other responses and try again. The trainee knows that each time he attempts to advance a counter tallies an additional "point." There is thus a certain aversive element to random selection of responses, a behavior that might otherwise be engendered. The subject, as noted earlier, has the original stimulus material available so that he can re-examine the problem before making another selection. Without this material, random selection would be the expected outcome.

2a. Covert-composed; self-corrected.



Frame 2a is an example of a covert-composed response. (The cross-hatched box was the convention used for "think of the answer that fits.") After the trainee thinks of the answer he then compares this covert response with the correct response. While, as noted, overt-written responses are "cheat proof" since they

cannot be changed once they have been written, covert responses are not under the same degree of control since nothing prevents the trainee from going on without making a covert response at all. The use of covert responses, however, speeds up the program by reducing writing time while at least strongly encouraging a (covertly) constructed response. It was felt that the inherent interest developed in the program material would provide the necessary incentive for proceeding through this type of frame in the correct manner. Observation of subjects performing on these programs indicated that this was the case. (Frequently such frames are followed by overt-written response frames requesting similar information. While trainees may not mind being "covertly" lazy and incorrect, they dislike being forced to exhibit this in overt behavior. The frequent intermixture of response modes is, of course, apparent to the trainee and results in close attention to each frame.)

Feedback for Frame 2a is identical with that described earlier for Frame 1a.

2b. Covert-composed; matched.

Before interception, the IND receives a last attention device from the computer. The Intercept Command Attention Display will show any final corrections in heading that are necessary when the time-to-go to [XXXXXXX] is one minute or less.

offset intercept home base

Frame 2b asks the student to compose an answer mentally (as did 2a), and then provides him a set of alternatives against which he matches the answer he covertly composed.

Feedback is the same as that described for Frame 1b.

The parallel relationship between Frames 1a - 2a and 1b - 2b should be noted. Except for the distinction between overt and covert responding, they follow the same format.

3a. Selective responses; conventional multiple choice.

The Intercept Command Attention Display gives a countdown in seconds-to-go to intercept, shows the latest bearing and range, and indicates any last minute correction in [XXXXXX] that should be made.

altitude speed heading

Frame 3a is a conventional multiple choice item, with the alternatives available to the trainee on the same frame that contains the stimulus material (noted here by being <u>above</u> the dotted line).

Feedback to the trainee as to the correctness of his response is the same as that used in the previous frames using a selection of alternatives (1b and 2b), namely, if correct, card (program) advances, if not correct, card (program) does not advance.

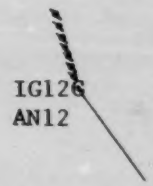
3b(1). Selective response; extended (universe) selection.

The letter [XXX] refers to a friendly aircraft whose flight path should be followed on the SID.

H U K P B I S F Y R

3b(2). Selective response; extended (universe) selection.

In the track below, the interceptor is ON Command Tracking. What letter in the track symbology gives this information?



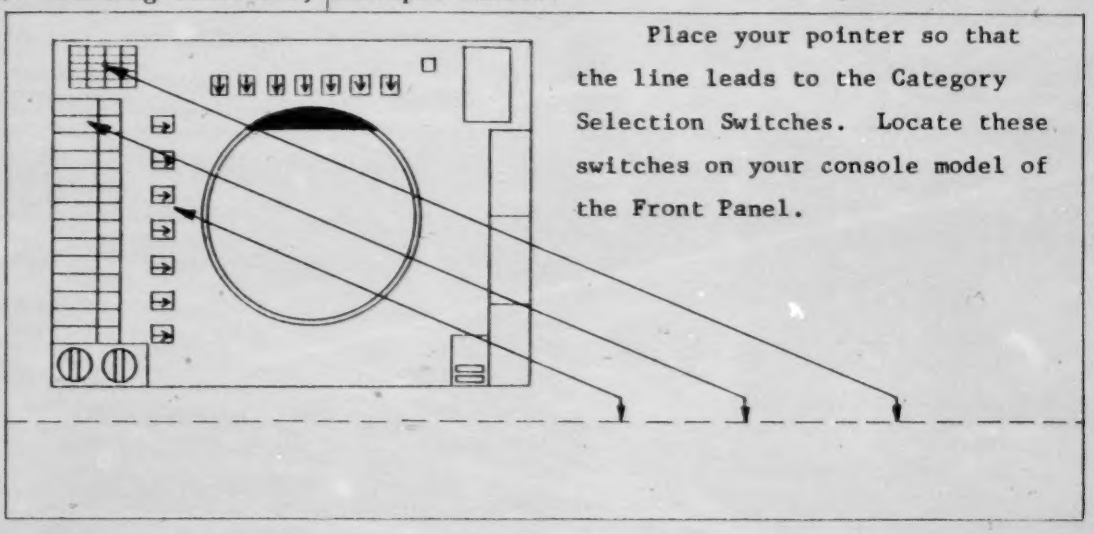
A C G I N

Frames 3b(1) and 3b(2) appear similar to 3a above, but notice that the number of choices available to the trainee is greater. They are thus examples of the composed-covert response rather than of the conventional multiple choice response. In both of these frames all of the possible answers have been included in the list of alternatives and, therefore, they have no "cue" value to the trainee. (This is not true in Frame 3a where, out of many possible answers, only three are presented to the trainee.) The trainee must covertly "compose" a response

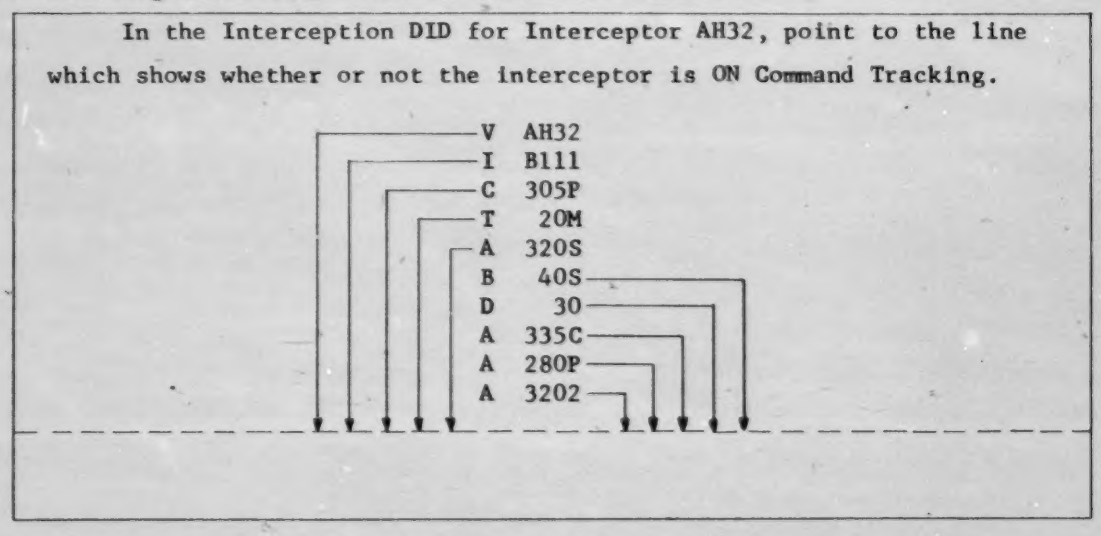
and then point to one of the alternative answers that match this response. This type of response mode is thus more closely identified functionally with Frame 2b than Frame 3a.

Feedback used in 3b(1) and 3b(2) is the same as for other frames using a selection of alternate responses (1b, 2b, and 3a).

4a. Pointing-selection; multiple choice.


Place your pointer so that the line leads to the Category Selection Switches. Locate these switches on your console model of the Front Panel.

4b. Pointing-selection; extended (universe) selection.



Frames 4a and 4b are examples of "pointing to" kinds of responses. Frame 4a is in the conventional multiple choice format, and as such is directly comparable in response and feedback mode to Frame 3a. Frame 4b is another example of the "extended (universe) selection" of responses and is thus directly comparable to Frame 3b.

Knowing where to look for information and where to find certain buttons and switches are important elements of both the Track Monitor and Intercept Director tasks. Frames such as those shown in 4a and 4b thus played an important role in both self-instructional programs, since they allowed the programmer to get relevant pointing and identification responses made by the trainee rather than less relevant (for these particular skills) verbal responses.

In an effort to avoid having the trainee make responses that were not germane to the material being covered there were some occasions when "frames" were included in the program that did not require a response term at all. The reason for using this type of "lecture" frame, as it might be called, is simply that no appropriate response was needed at that point but some general program information was deemed helpful to the trainee. Thus, at the end of a sequence covering the nomenclature of the SID console and before the sequence covering the nomenclature of the wing panel, an appropriate "frame" would be as follows: "You have now completed that portion of the program dealing with the identification of switches on the IND main console. The program will now go on to cover the IND wing panel." Such transitional material plays an important part in helping the subject follow the organization that has been built into the material. It does not, however, lend itself to the construction of meaningful response terms. Some of this type of material can be found scattered throughout both programs.

2. Cueing.

Briefly, cueing or prompting is a method for eliciting from the trainee a response in connection with a stimulus which was not previously associated with that response. This is done initially by giving the trainee hints that help him make the appropriate response. As the response becomes learned (associated with the stimulus), the hints, or cues, are reduced until finally the trainee can make the

response to the criterion stimulus alone.

Cues and prompts are generally considered as the means by which the trainee is helped in making the correct response within a frame. This type of internal cueing will be discussed in detail, with examples, on the following pages. There is another, broader kind of cueing that should be mentioned first. A naive subject entering a program brings with him certain knowledges and skills that relate to his aptitude or knowledge in the area being covered. (This is an example of a "learner variable" influencing "programming variables," as discussed briefly in the Introduction.) It is necessary for the programmer to utilize this kind of available information in getting the trainee to make initially appropriate responses. This form of cueing may be called "external."

Thus, in developing the programs for SAGE, a basic assumption was made that the trainee had absolutely no prior knowledge of SAGE but was of at least average intelligence. This was a "working" assumption. (It was known that some trainees would participate in the evaluation of the programs who had SAGE experience. The problems associated with using programs with groups having dissimilar entrance skill, knowledge and/or aptitude levels is discussed in a later section of this report.) Early response terms had to be connected originally to something the average subject would understand. As an example, in the TM program an analogy was made in the first few frames between the general duties of the TM and a lifeguard (scanning, corrective action, preventive action, etc.). This analogy gave the program writer a starting point of common knowledge from which he could progress into specific SAGE terminology and concepts. The IND program required less of this since the IND task is inherently more closely related to activities which might easily be described and related to the trainees existing repertory of information. Flying an interceptor aircraft against an enemy aircraft and trying to shoot the enemy aircraft down is a familiar concept. Searching a situation display, looking for high priority tracks and keeping their merit high, etc., as the TM must do, is not so familiar.

Cues used early in both programs, therefore, were frequently of this external type. It was not important in terms of final job proficiency to teach the TM

trainee, for example, that his job is similar to that of a lifeguard. As soon as this analogy was made it was dropped and used as an implicit basis for going on to more specific and more job-related items. The literature in self-instructional techniques does not generally cover this form of cueing, perhaps because many programs (e.g., academic) are written in areas that have large, existing, inherent contextual prompts.

It is generally agreed that internal cues should gradually be decreased in strength as response strength increases (Briggs, 1960; Glaser, 1960; Lumsdaine, 1959b; Skinner, 1958). The difficulty presented to the frame writer is that he must decide when to fade out the cue strength, i.e., how rapidly, how many repetitions with prompts are needed, and when he can introduce nonprompted frames (Cook & Spitzer, 1960; Angell & Lumsdaine, 1960). This, in turn, depends on his ability to utilize previously built-up responses and his ability to "compose" a frame that has the greatest intrinsic cue strength without giving away the answer.

It is frequently possible to insure the elicitation of the correct response by using purely semantic prompts (such as the word "also" in the statements: "Track H107 is a Faker track. Track A049 is also a [ ] track."). This does not in and of itself provide a suitable environment in which to make the response and thus, while insuring correctness, it may not insure the development of appropriate terminal skills. It is also possible (and tempting) to let the ease of cueing alone determine the response to be made. This also has the advantage of insuring that the trainee will make the correct response, but has the disadvantage of teaching the trainee responses that are irrelevant. In reviewing frames and in empirically testing frames in the two SAGE programs, many were found which contained full or obvious prompts (leading to echoic or copy responses), even though response strength was built up to a fairly high level and could therefore have been less completely cued. These frames were rewritten so that they provided less of a crutch and more of a challenge to the trainee.

The following general guides were used in considering the development of appropriate cues:

1. Cues should only be sufficient to elicit the response. Anything

more than this is redundant.

2. Cues should, to the greatest extent possible, occur in contextually rich environments (those related to terminal tasks).

3. Cues should never determine the selection of responses.

4. The best cues in terms of rapid subject matter development are, or are closely related to, earlier learned responses.

Item (1) is easier to state than to follow. It is difficult to determine just what average level of response strength exists at any given point in the development of a new term or concept. Figure 1 conceptualizes the relationship between cue strength and criterion response strength as a function of the number of frames needed to achieve mastery.

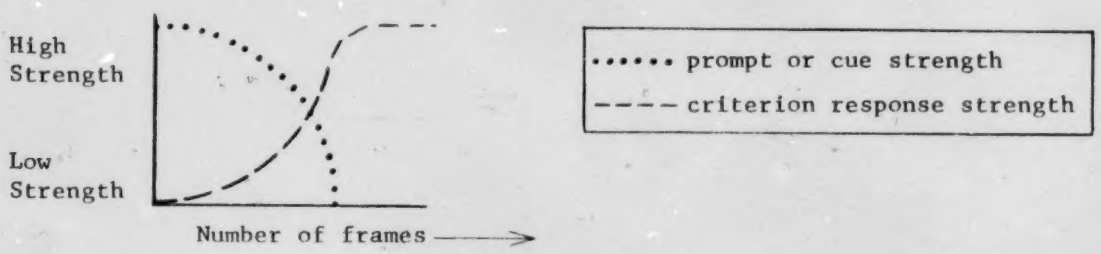


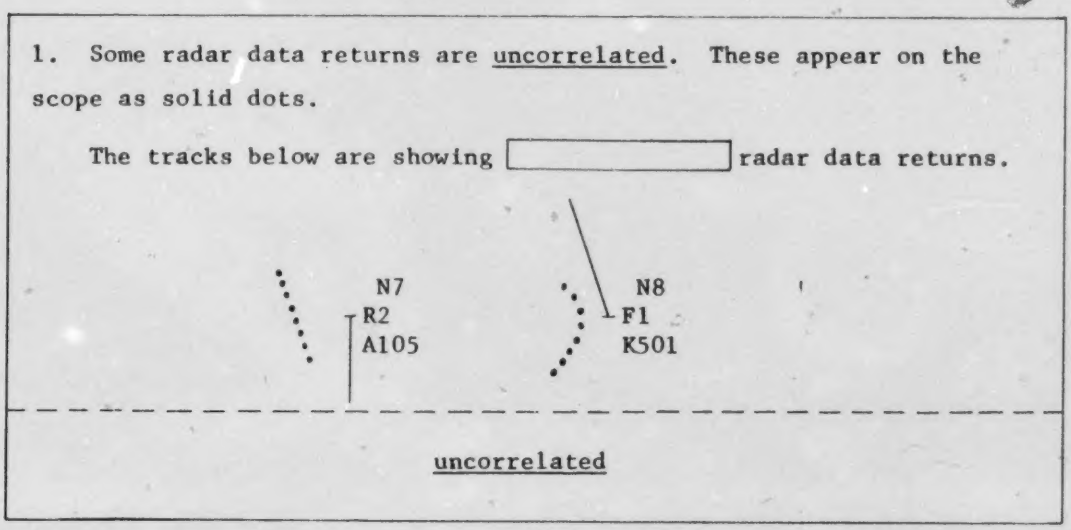
Fig. 1. Relationship between cue strength and criterion response strength.

The important thing to note is that as soon as the criterion response can be made without the use of prompts (again other than those contained in the actual terminal situation in which the response is elicited), the prompts are dropped. The point at which this occurs should be reached as early as possible. Experience with the TM and IND programs indicated that criterion responses consisting of new terms can be built up in four or five frames. More complex skills require more frames. Seventeen frames were used in teaching the relationship between IND,

computer, and pilot in the IND program. The information taught, in either case, was used many more times in various contexts in remaining portions of the program.

As a final observation relating to the general problem of cue strength (before citing specific applications) it should be noted that two kinds of errors can be made in deciding when to drop the cueing for a particular response, too early and too late. If done too early, learning is impaired because the student makes errors. If done too late, unnecessary repetition and perhaps boredom is introduced into the program. Both should be avoided, but unless there is another "out" (which will be covered under Section 5) the latter is probably the lesser of the two evils in terms of achieving program objectives in a continuous-discourse program. This would not be of corresponding concern in discrete-item programs, where an error on one frame would have no affect on the probability of making an error on a subsequent frame.

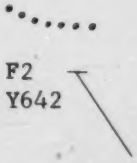
A short segment from the TM program will now be examined and analyzed, with emphasis on cueing techniques as applied in both self-instructional programs:



38

2. Uncorrelated radar data returns appear in track displays as solid dots. Here are some examples:

Is track number Y642 below showing correlated or uncorrelated radar data?



correlated uncorrelated

3. Data returns which appear on the SID as solid dots are [ ] radar data returns.

uncorrelated

4. On SID 2, track number G372 is showing uncorrelated radar data. What is the track number of another track which is also showing an uncorrelated radar data trail?

H456 Y056 EL04 MJ01 P192 A294

5. Is track number H104 on SID 2 showing correlated or uncorrelated radar data?

correlated uncorrelated

Frame 1 depends almost entirely on the fact that the trainee already knows the term "radar data returns." As a matter of fact, this whole series of frames hinges on that assumption. (This is why, as noted above, when in doubt as to response strength it is better to err on the side of redundancy. In case this response was not learned, these frames would have greatly reduced cue value.) The first sentence is a simple declarative one associating some radar data with

the term "uncorrelated." Since the trainees have already been taught other forms of radar data, the meaning of the word "some" should be obvious. The second sentence is also straightforward and only requires that the subject associate the word "these" with the term "uncorrelated." (Perhaps a stronger sentence would have been "These uncorrelated radar data returns appear on the scope as solid dots." However, brevity is desirable so long as it does not interfere with meaning or learning efficiency.) The essence of the second sentence is the opportunity of the trainee to learn that uncorrelated data appear as solid dots. In the third sentence the trainee applies what he has learned by making the response. The third sentence requires only that the trainee recognize that the tracks below do indeed have solid dots and are therefore uncorrelated. The term "track," by the way, was also previously defined and taught.

Frame 1 employs a full prompt, i.e., all the information needed to make the response is contained within the frame. Frame 1 could also be said to employ a copying response or echoic response, since the response term is given to the trainee in the stimulus material. Most frames which introduce a new term or concept contain this kind of full prompt. Attempts to avoid it usually involve such devious and involved circumlocutions that it tends to obscure the development of the subject matter. Thus, one version of Frame 1 might be:

The opposite of cluttered is uncluttered.
The opposite of likely is unlikely.
The opposite of correlated is [ ].

But notice how little one has progressed in the development of the subject matter. A program of this type would be considerably longer, probably boring to the trainee, and perhaps less effective. Notice in contrast that while Frame 1 is a full prompt frame, it does require attention to the frame's content. It must be read with understanding -- it cannot be given a cursory glance.

Empirical data from pre-testing program segments revealed that subjects could progress correctly and more rapidly using full prompts (in context) in frames

introducing new terms or concepts. They should, of course, be avoided as the material becomes part of the subject's repertory (as have "radar data" and "tracks" as used in Frame 1).

The technique of underlining response terms the first few times they are used is one which was employed throughout both programs. It seems to have obvious attention-getting value, and therefore can be assumed to have "cue" properties. SOLID CAPITALIZATION and the setting off of words and/or phrases, can also be used in this fashion.

Frame 2 carries the concept of "uncorrelated" one step further in that it asks a subject to make a judgment, i.e., to compare the concept of "uncorrelated" with the previous learned concept "correlated" and decide on the basis of information contained in the frame and the track shown whether it is one or the other. In a sense, the prompt or cue for this frame is complete. The trainee probably could answer Frame 2 without having had Frame 1. (As a matter of fact, the average person could get either frame "right" without having had any of the previous frames, but without knowing why. Correct responses, again, are necessary but not sufficient for task-related learning to take place.) Frame 1 contains information which thus helps the trainee to understand why he is getting Frame 2 right. The trainee might otherwise be confused by Frame 2 due to the fact that up until that point he knew only about one kind of radar data, namely, "correlated." He was not aware that there were other types. Without this concept (that some radar data is "uncorrelated") Frame 2, while fully prompted, would perhaps leave room for doubt and speculation (correct or incorrect) about the concept "uncorrelated." Empirical testing of the program would not reveal this type of interdependency and gradual build-up of concepts where fully prompted frames are concerned. It would show up later (if the material being taught has any value -- and of course it does) as the trainee revealed some confusion with respect to the concept under discussion at this point.

Frame 3 is an unprompted frame or terminal response frame. It requires that the response being taught be made with only normal contextual cues at the verbal level. This frame could also be referred to as a confirmation frame (Cook & Spitzer, 1960).

Note that up until this point the subject matter has been basically an academic-identification skill on the verbal level. The verbal repertory has now been established and associated with the proper symbols so that the skill is now ready to be applied to the criterion task. It would be possible to stop at this point and assume that the trainee would make the appropriate responses when he was put in a situation requiring knowledge of classes of radar data in the performance of his job. However, the program described here carried the trainee to a skill level more closely approaching that actually found on the job, and thus the necessary cues must be found to affect this transfer.

Frame 4 requires the use of an ancillary piece of equipment which made it possible for the trainee to view a simulated cathode ray tube display such as is used by the TM and IND on the job. At this particular point in the program this simulated display would be on a "steady" mode of operation. After the trainee had become sufficiently familiar with the various kinds of information and symbols used in these displays, he would view the display in a "flashing" mode which simulated the normal on-off cycle of operation for this display as it occurs on an actual operator's console. ("SID 2" refers to a particular Situation Information Display which is inserted into this simulated unit by the trainee.)[1]

Note that the first requirement of this frame is that the trainee find Track Number G372 and further that he note that it is showing uncorrelated radar data. He is not told that the reason it is showing uncorrelated radar data is that it consists of solid dots. In effect this sentence is repeating the information that uncorrelated data consists of solid dots but is doing it indirectly by asking him to find the track that is so displayed.

Frame 4 further challenges the subject by asking him to locate another track which is <u>also</u> showing uncorrelated data. This requires some searching

[1]This ancillary simulated equipment is described in the report dealing with equipment (ESD-TN-61-47).

behavior (although early displays employed only a limited number of tracks). The cues here are of a subtler nature but sufficient to accomplish the task. They have a distinct added advantage of being less obvious and leading to a more inherently interesting task than producing written responses.

Although this discussion is about cueing, the response mode used in this instance should be noted as having a bearing on the cue strength of the frame since the available responses are all visible to the trainee. The cue value of response terms thus displayed is of some importance. As previously discussed, when the visible response terms represent the total universe of possible response terms, they have no real cue value. In this case, all the track numbers on the display have been included in the various response terms listed as alternative answers. Thus, except for the fact that the trainee knows he is looking for a track number, which he would know from the frame anyway, they provide him with no assistance.

When new terms are being taught and hooked on to known terms, it is sometimes important that the directionality of stimulus and response be reversed. Up to this point the response term has always been "uncorrelated." However, the analysis of the task revealed that the directionality of the concept, "solid dots -- uncorrelated," was sometimes reversed so that the operator needed to look for "uncorrelated data" (stimulus) which he would know he had found when he saw the "solid dots" (response). Notice, therefore, that Frame 4 has reversed the stimulus response term in that the trainee is now searching for a track having solid dots (the response) which is showing uncorrelated data (the stimulus).

Frame 5 is very similar to Frame 2 except that it is asking the trainee to apply to a simulated task situation the verbal skills developed earlier. It is also a nonprompted confirmation frame. The cue value of the response terms visible to the trainee is limited because the frame itself indicates that these are the only two possible alternatives available. To have the trainee write the response at this point would only draw out the program and serve no useful purpose (except, perhaps, record keeping).

The frame following "5" goes on to other material. However, the knowledge gained in this segment is applied in many situations throughout the rest of the program in more and more complex environments and is used as cues for the development of other responses.

3. Size of step.

Size of step (frame) is sometimes discussed in terms of the amount of material covered within a frame and sometimes referred to in terms of the distance covered in the program per number of frames (Lumsdaine, 1960a). The latter is more correctly a function of the density of the program and the former is more correctly involved with the size of step problem. Density of programming will be covered in the next section dealing with organization of frames.

A number of conditions contribute to the programmer's decision as to how much material to include within a single frame. As a general rule, a single response is the end product of a single frame. The frame contains the cues and prompts sufficient to elicit that response. In practice, however, there may be occasions when more than one response is called for in a frame as, for example, in review sequences.

In addition, some frames are of the type requiring considerable rehearsal of earlier learned material in order to supply the necessary prompts and/or the proper contextual environment for the response being made. This is particularly true where subject matter is broken up for various reasons and the thread of a concept is picked up at a later point in the program. This is shown in Frame 1 below. A brief review of velocity vector is included before some additional characteristics of this material are explained and a response called for.

1. The velocity vector, you will recall, is the computer's prediction of the aircraft's future heading and speed. The vector originates at the same place in which the E character of the symbology appears. At the origin of the velocity vector is a bright spot called the "point feature."

The E character of the symbology and the [ ] [ ] of the velocity vector appear at the same place in a track display.

---

point feature

Frame 2 is also lengthy in comparison with the average frame size in the two programs. It represents a type of frame that was difficult to handle because the close logical relationship of subject matter tended to require that it be kept together while it did not lend itself to further breakdown into additional response elements. In general, frames of the length represented by both Frame 1 and Frame 2 were shortened and divided into two or more frames. If they were not reduced, they were usually repeated at least once in slightly different versions to insure learning. (Thus, density can be increased to compensate for increased frame size.)

2. The radar data returns represent the actual present and recent past locations of an aircraft. The brightest radar data return is the most recent one and occurs immediately before the vector. It is called the Present Data because it indicates where the aircraft is at present. The other radar returns show the course of the aircraft for about the past two minutes.

The TM can determine the present location of an aircraft by the [ ] [ ] which is the first and brightest data return before the vector.

present data

Frame 3 is long primarily because of the number of responses called for. It would be unacceptable as a teaching frame but was sometimes used as a review frame. While it would be fairly easy to break this frame down into individual response units, it would serve no particular purpose to do so and would result in a greater number of frames and the necessity for the student to move to a new frame after each response and refer to a new set of stimulus material in each frame. A disadvantage in this method of review is that it is not diagnostic within the program, i.e., it does not lend itself to branching sequences which would provide review of additional needed material.

Review frames of this multi-response type are used only after the appropriate responses have been sufficiently practiced and adequately learned. Errors made on a multi-response test frame would be particularly aversive to trainees who would feel that they were being given an impossible task. On the other hand, multi-response frames have great reinforcement value when the trainee has been brought up to a skill level that would enable him to respond correctly. Thus such frames were used with great caution and only after considerable drill with the subject matter on a small step basis.

3. Track G166 is a [ ] track, in [ ] merit, being told [ ] to the [ ] sector for [ ]. Its altitude is [ ] feet, and the height age is [ ].	F G166 POKW A 150U F 01 S 0225 G EH G 3810 C 404
Friendly . . . POOR . . . out . . . Chicago . . . warning . . . 15,000 . . . unreliable	

Frame 4 illustrates an additional reason for extending frame length. It varies the usual small step format in that it presents a problem for the trainee to solve. It contains rather full prompts but they are not made completely obvious. The trainee must read the stimulus material carefully before he can determine the correct response. Problem frames of this type serve to break up the monotony of very small step frames and are particularly useful as criterion frames for problem solving subject matter. This type of frame should be challenging to the trainee but should not be beyond his capacity if he reads the material carefully.

Problem frames of this type do not, in these programs, reach the level of complexity that is typical of frames prepared in formats sometimes referred to as using "intrinsic" programming. These latter programs sometimes contain frames of very large size, covering enough material to completely fill a page in a textbook, not as review, but as teaching. Problems are then given the trainee to solve based on this expository material. Depending upon his response he would be branched to other frames -- remedial frames if he made an error (a likely occurrence in view of the density--difficulty--as well as size of step), and "new" frames if he did not make an error.

It was considered that this approach was inappropriate, theoretically, in as much as it provided too much opportunity for the trainee to make incorrect

responses which would have to be reshaped in subsequent segments. It was considered preferable to accomplish this "shaping" before the response was called for. Problem solving would thus be a rewarding and not an aversive experience.

4. A control handover may not only be an external one between two SAGE sectors, but it could also be an internal reassignment. When an internal handover is made, the letter of the sector in which the interceptor is flying will appear twice in the DID.

An [redacted] handover is being made on Interceptor GG09 from IND 2-2 to IND 2-3.

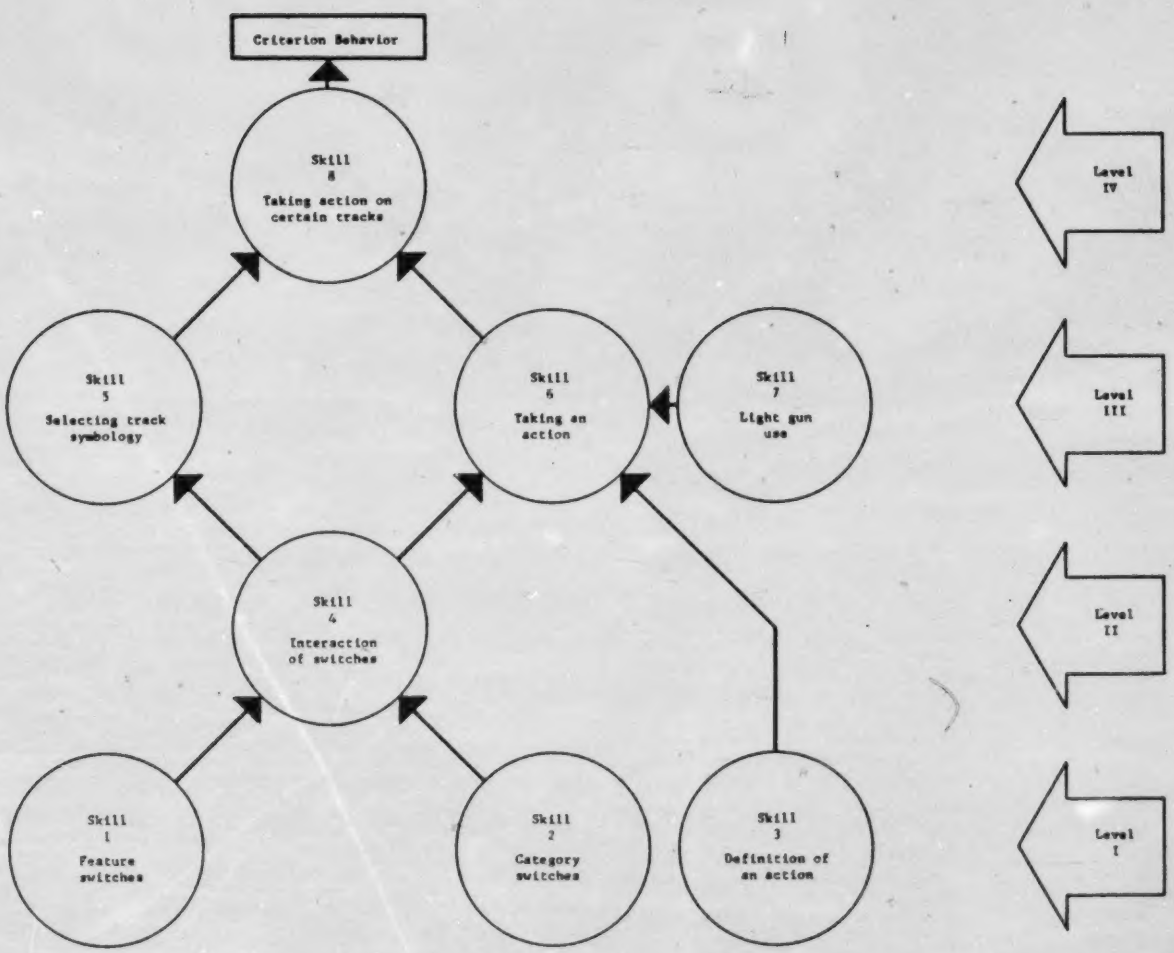
internal external

I	GG09
	G
A	315
F	01
S	0709
F	GAR2
R	BAFI
I	2223
A	1745
A	2186

4. Organization of frames.

The overall organization of each program was derived from the task analyses performed for each task (covered in ESD-TN-61-52). This organization, however, does not simply reflect the order in which the various steps of the task are actually performed on the job but more importantly reflects the interdependency of various skills and behaviors which need to be developed in building toward the criterion behavior. Logical subject matter dependency relationships are thus the necessary (but not sufficient) determiners of the organization of the program. (One could not teach the TM how to request various kinds of information on the SID until after he understood the meaning and interaction of the Feature and Category Switches and the meaning of the symbols.)

The resulting organizational structure tended to exhibit a cyclical pattern since terms, skills, and concepts were reintroduced in new contexts as the proficiency level of the trainee was developed. This could be represented as follows:



Initial Behavioral Repertory

Skill 1 is introduced at Level I, integrated with Skill 4 at Level II, reintegrated with Skills 5 and 6 at Level III, and finally with Skill 8 at Level IV. By this time it has lost its separate identity. (The latter occurs when skills and behaviors are essentially propaedeutic in nature.) This complex building of skills and knowledges was characteristic within segments as well as throughout the general structure of the programs.

Tables 1 and 2 contain brief descriptions of the program segments for both the TM and IND programs in the order of their occurrence. The circular development of material can be noted in Table 2. Segment 1 contains a very brief description of a standard intercept mission. After learning a good deal about the equipment the trainee is required to use, an outline of a mission is reintroduced in Segment 4. This time considerably more detail can be introduced since the trainee has now developed a rather large repertory of relevant information. Finally, in the tenth segment, a mission is again covered, but this time in great detail, since most all the relevant skills and behaviors have been developed in previous segments of the program.

As noted earlier, the TM program was considered to be the more difficult of the two in terms of understanding the general nature of the task. For this reason it was decided that the first objective of the TM program would be to teach the trainee how to take a specific action by giving him a relatively "thin" program covering symbology, switch actions, and track problems. Once the trainee had learned an action, even if at a rather inadequate level, the programmer would have something to which he could relate the other skills needed by the TM. This would give the overall job a structure which it otherwise lacks. Thus, in Table 1 it can be seen that reinitiate action is covered in an introductory (thin) fashion in the first segment. It is covered again and in greater detail in the second segment.

Table 1

Organizational Structure of Track Monitor Self-Instructional Program

Program Segment	Title	Description	Number of Frames
1	Introduction to SAGE, the console, the SID, and TM actions	Covers the SAGE System in general and the TM's mission in particular. Describes the SID, introduces the concept of "track," and teaches meaning of merit and identity symbols. Discusses Feature and Category Switches. Provides an introduction to Reinitiate Action.	352
--	Track Identity Symbols	Paired-associate format.	*
2	Track Problems and Actions	Detailed coverage of track problems and of Reinitiate, Dead Reckon, Exchange, Lost, Track History, and Attention Actions.	546
3	"Reference" Switches	Covers the AIRBASES, GEOREF, and ADIZ Switches, and the Expansion and Off-Centering Buttons.	145
4	Priority	Covers the criteria for determining priority, including track identity and merit, track location, and weapons committment.	126
5	Established and Non-Established Tracks	Covers Lost, Dropped, Extrapolated, Manual Input, and Crosstold Tracks.	106
6	A, B, and E Characters	Teaches meaning of the A, B, and E characters of the track symbology.	254
--	Sector Designator Symbols	Paired-associate format.	*
7	The Track Tote DID	Covers the Track Tote and Situation Alarm DIDs including meaning of all symbology.	173
		Total Number of Frames	1,702**

*The paired-associate format used for these segments is discussed later in a separate section.

**Excluding paired-associate material.

Table 2

Organizational Structure of Intercept Director Self-Instructional Program

Program Segment Title	Description	Number of Frames
1 Introduction (SAGE)	Explains in general terms the SAGE System and how the Air Surveillance Branch and, more particularly, the Weapons Branch, fit into this system. Duties of IND are briefly reviewed with specific reference to the relationship between computer, pilot, and IND/INT team in the conduct of a mission.	91
2 Main Console	Includes Feature and Category Switch Action and interaction of these with SID display. Includes discussion of data, vectors, and enough symbology to clarify the Feature Switch Actions.	371
-- Phonetic Alphabet	Paired-associate format. One half hour scheduled time.	*
3 Wing Panels and Auxiliary Console	All switch nomenclature, location, module interaction, etc.	252
4 Outline of Mission	A mission is covered from beginning to end, hitting only the major elements involving actions by the IND/INT team.	137
-- Phonetic Alphabet	Paired-associate format. Review (not to exceed one half hour).	*
5 SID Symbology	Includes track symbology, intercept point symbology and attention displays.	319
6 Interceptor DID	Covers all symbols used in this DID.	230
-- Brevity Code	Paired-associate format. Covers 45 of the more important words and terms used in the radio transmission between IND and pilot. One half hour scheduled time.	*
7 Non-Interceptor DID	Covers all symbols used in this DID.	162

Table 2 Continued

Program Segment Title	Description	Number of Frames
-- Brevity Code	Paired-associate format. Covers an additional 48 terms. One half hour scheduled time.	*
8 Interception DID	Covers all symbols used in this DID.	132
9 RTB DID	Covers all symbols used in this DID.	65
-- Brevity Code	Paired-associate format. Review of total segment (not to exceed 3/4 hour).	*
10 Standard Intercept Mission	Covers a complete mission in detail, emphasizing the normal sequence of actions and radio communications between the IND and the pilot. Includes DIDs requested and how they are used, the use made of SID symbology, how and what switch actions are taken, when pilot and IND contact each other, and the content of the typical radio communication between them. Includes the use of command tracking and data link.	685
	Total Number of Frames	2,444**

*The paired-associate format used for these segments is discussed later in a separate section.

**Excluding paired-associate material.

It will be noted that included in Tables 1 and 2 are program materials referred to as "paired-associate." While these materials were a part of the two programs, they were physically separate drill exercises prepared in booklets. The trainee was referred from time to time to these booklets by the program. The symbolic skills represented by these paired-associate segments were identified as being essentially different from those which were included within the continuous-discourse programs. This distinction was discussed earlier (page 11) under the section dealing with symbolic skills. The rationale for treating this material in a different format is discussed in relation to a study conducted to investigate programming methodology as applied to paired-associate material, a description of which is contained at the end of this section (page 61 ff.).

In addition to overall program organization, certain organizational elements were built into and can be identified within subject matter segments. The schema for the development of material within these segments was, of course, influenced by the nature of the subject matter, but in general tended to reflect the structure indicated in Table 3. Also included in this table is an indication of the general level of program density that is associated with each item.

Table 3

Organizational Pattern Within Segments and Density of Programming (General)

Sub-Segments or Subject Matter Areas	Density of Program
a. Introductory material	Thin
b. Teaching material	Dense
c. Review of B	Thin
d. Teaching material	Dense
e. Review of D and integration with B	Generally thin
f. Teaching material	Dense
g. Review of F and integration with D and B	Generally thin
h. Summary review integrating B, D, and F	Thin

The decision to review previous material before going on with the development of new material was judgmental. Some subject matter was so closely knit together with the overall program that it "reviewed itself" as the program progressed (track merit, for example). Other subject matter needed to be reviewed rather frequently, such as the longer DIDs, since it was not possible to work it into the main stream of the program.

The logical (as opposed to subject matter) organization of frames within instructional units covering a single item or unit of information in general tended to follow the "Ruleg" system developed by Homme, et al., (Evans, Homme, & Glaser, 1960), i.e., principles or rules were explained first, followed by specific examples with perhaps a restatement of the principle or rule at the end of the unit of instruction. As in all of these organizational schema, the subject matter influenced the manner in which individual instructional items were covered and some instances in which specific examples were covered first and principles or rules extracted from them can be identified in both programs.

5. Branching.

Branching is a technique whereby the structure of a self-instructional program is varied based on some identifiable characteristic or behavior of the learner. In a nonbranching or linear program all subjects receive all frames regardless of subject characteristics or subject performance during the course of the program. In a branching program, the decision is made by the programmer during program development that the subject should receive a different version of the program because of his performance (speed, and/or accuracy), his aptitude level, or other relevant characteristics. This type of program is sometimes referred to as a "multi-track" program. Usually the subroutines, or branches, are temporary in nature; the subject is returned to the main body of the program shortly after leaving it. Programs have been written utilizing extended subroutines, although these have usually reflected content variables (e.g., trouble-shooting behavior) rather than learner variables (Crowder, 1960).

In the present instance, no attempt was made to branch at the segment level,

i.e., all subjects were required to go through all segments.[1] However, branching within segments was applied to account for two subject dependent variables:

1. difficulty level of material, and
2. the amount of review needed.

Thus, to the extent that this technique was employed, slower subjects received additional (denser) instructional material and review and the more rapid learner (or the learner with a higher developed initial skill level) received a thinner program with less review. In this manner, the program tended to adjust itself in level to the needs of the individual subject. (This is in addition to the automatic adjustment in speed of presentation which is characteristics of all self-paced programs.)

Obviously the ability to utilize some form of internal branching is dependent on the characteristics of the equipment available to the programmer. In the present instance, the device designed by the project staff and built specifically for the IND program provided for branching sequences of the type described. The equipment used with the TM program (modified from existing equipment) did not provide for branching. (These devices are described in detail in ESD-TN-61-47.) Thus the TM program could be characterized as a linear program.

The three frames reproduced below from the IND program are an example of the simplest form of branching utilized.

[1] A minor exception to this is noted in the concluding section of this report. The wisdom of this nonsegment branching approach is also discussed in this section, as well as in the report dealing with the evaluation of the results from the on-the-site field evaluation of the two programs (ESD-TN-61-51).

1. If the RTB DID for Falmouth Airbase indicated that the base was closed, you would request an RTB DID for an appropriate [XXXXXXXX] base.

home alternate

---

2. Your answer to the previous frame was incorrect. If the interceptor had been scrambled from Falmouth, as was previously stated, then Falmouth is its home base. Alternate bases are other bases that can be used when the home base is closed. Thus, if the RTB DID for Falmouth Airbase indicated that the base was closed, you would request an RTB DID for an appropriate [ ] base.

alternate

3. Selection of an airbase depends not only on weather conditions, but also on the distance to the base and the amount of fuel and oxygen remaining. Distance, time, and heading to the base are given in the RTB DID. Therefore, to help in selecting an airbase for RTB, the IND will request a fuel and oxygen report from the pilot. He will also need to request a DID. Which DID will the IND request?

Track DID RTB DID Interception DID

Frame 1 is the final review statement of a concept that was previously taught. It is an important concept, one that the trainee should be certain of having before proceeding on to additional material. One way to insure that this concept is well learned is to include additional instructional frames in the teaching of this particular point. It was felt, however, that most subjects would have learned the appropriate response by this time and that additional repetition of this material would be boring to them and wasteful of their time.

In point of fact, pre-testing the material would reveal that this was the case. It should be remembered, however, that while empirical tryout is an excellent method of determining which parts of a program are too thin, it is not diagnostic in determining which parts of the material are overprogrammed, since in the latter case all trainees would make all the correct responses. The view favored here is to use a fairly large sample of trainees representing the range of skills, I.Q., etc., from the using population. The full program, utilizing all branches, is the one minimally needed for the low end of the population. The "main track" of the program is the one minimally needed for

the high end. Those in-between will branch as needed.[1]

Tryout of program material should reveal, upon close questioning, the source of the confusion for those trainees who miss a frame. For example, let us say that Frame 1 was originally a write-in frame and that a few trainees wrote the response "home." "Home" was then used as the alternate answer in the branching sequence which was built to replace the single write-in frame.

Operationally, Frame 1 was used as follows: the correct response is the term "alternate"; the incorrect response is "home." Since this is a simple multiple choice item, the subject points to the response he considers appropriate and advances. If he selects the term "alternate," he advances directly to Frame 3, skipping Frame 2. If he selects the response term "home" he branches to Frame 2.

Frame 2 summarizes and reviews the main points covered in the preceding material, some of which the subject must have misunderstood or otherwise he would not have indicated the wrong response in the previous frame. Frame 2 also repeats the problem presented in the previous frame, although, in this instance, it requires an overt-written response rather than a covert response. Where terms are involved, this forced overt behavior should raise their response strength to an acceptable level.

Frame 3 is the re-entry point for those trainees who were routed through the branching frame, 2, and is the "next" frame for those who made the correct response in Frame 1. This simple form of branching could be diagrammed as follows:

---

[1] The term "minimally" should not be taken to mean that <u>just</u> being able to emit all the correct responses, even assuming they are all appropriate responses, is synonymous with an ideal program. To the extent that extended retention and transfer are important elements to consider, overlearned responses may, in fact, be necessary. "Minimally" would, in this context, mean the least possible program to <u>meet program objectives</u>, not simply (or only) to make correct responses. Empirical tryout does not, in itself, indicate to what extent these ultimate program objectives have been met, and charges of "too much repetition" and "boredom" would have to be considered in the light of such objectives.

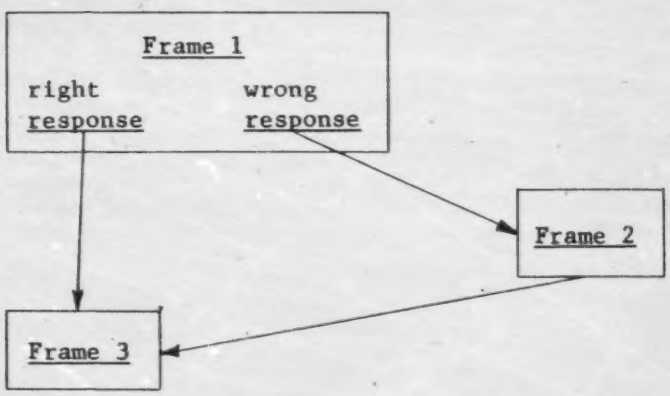


Fig. 2. Simple single track branching sequence.

On the following pages a final sample of frames from the IND program is shown in order to demonstrate a more complex application of branching as well as a few additional features not covered in any of the frames previously referred to.

Figure 3 conceptualizes this more complex sequence and should be studied before reading through the individual frames.

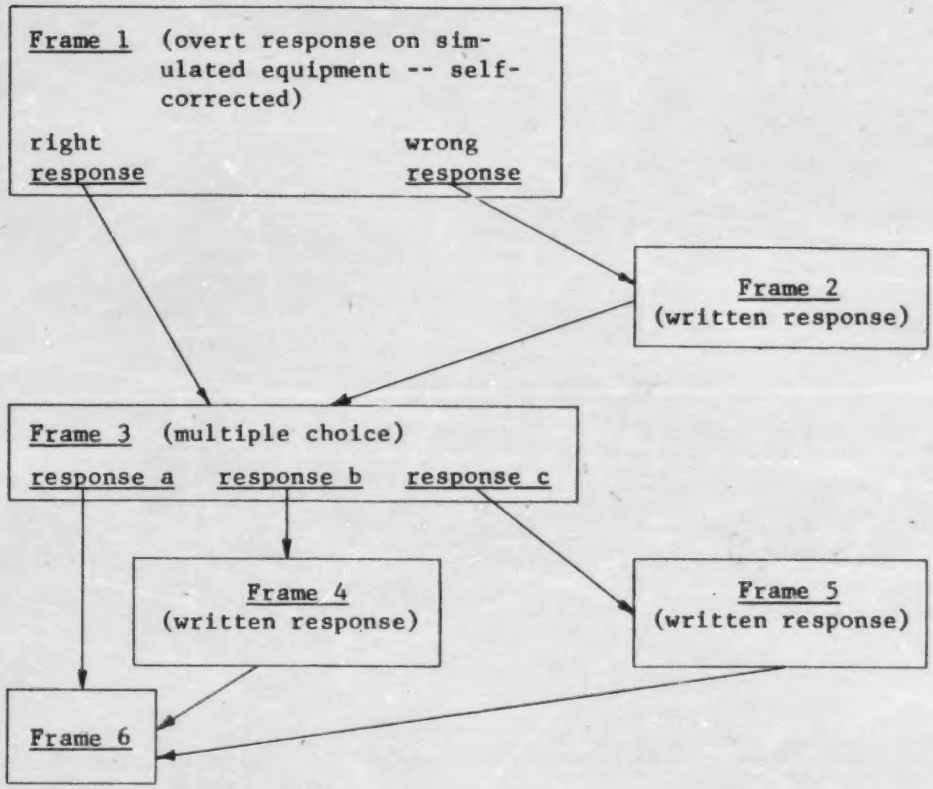


Fig. 3. A multi-track branching sequence.

1. All the necessary buttons have been inserted. You are now ready to make your action effective, or, in other words, to tell the computer to "go ahead and take the action." Press the button you would use for this purpose on your Wing Panel. Then go on to the next frame.

---

1. If you pressed the Activate (ACT) Button on the Wing Panel, place the pointer

HERE

(If here, trainee goes to #3)

2. If you did not press the Activate (ACT) Button on the Wing Panel, place the pointer

HERE

(If here, trainee goes to #2)

2. The Activate Button is located at the bottom right-hand corner of the IND Wing Panel and is labeled "ACT." Press it in now. The purpose of this button is to [ ], or make effective, the insertions you have previously made in your console.

---

activate

(to #3)

3. Instead of concluding this action with the Activate Button, an alternate procedure is to aim the light gun at the track's point feature. Since the light gun action itself would indicate to the computer on which track the action is to be taken there is no need to press in the [XXXXXXX] [XXXXXX].

track number | action buttons | release buttons

(to #6) (to #4) (to #5)

4. Your answer "action buttons" was wrong. You always have to use the action buttons on the console to give the computer precise instructions as to just what kind of action is to be taken on a track. But, when you aim the light gun at the point feature of a track, you automatically indicate on which track the action is to be taken. Therefore, you do not need to insert the [ ] [ ] on the Wing Panel.

track number

(to #6)

5. Your answer "release buttons" was wrong. The Release Buttons are always used at the beginning of every action to clear your console.

Since the computer must know on which track to take an action, you must designate the track number either by inserting the track number in the Wing Panel (and then using the Activate Button) or by aiming the light gun at the track's point feature. When the light gun is used, it automatically tells the computer on which track action is to be taken, and it is not necessary, therefore, to insert the [ ] [ ].

---

track number

(to #6)

Frame 1 in the above sequence is of interest not only because it "introduces" the branching sequence but because it involves a type of response and feedback not contained in any of the previously discussed frames. The subject is requested to make his response on the simulated console equipment which was part of his training station complex. This actually was the final frame in a series that included all the necessary steps in order to take a particular kind of action. Previous frames have instructed him to insert the various required buttons. All actions end with some method of activation and because this point had been covered earlier, it was assumed that most subjects would be able to get this frame correct from the contextual cues contained therein.

The response alternatives to this frame consist of the material which is below the dotted line. Here the trainee is asked to "judge" his own response to the stimulus card and proceed accordingly. As indicated earlier for similar types of frames, the trainee could respond as if he had made the correct button insertion even though he had, in fact, not made it. It was believed, and evidence from the field testing substantiated that individuals going through a program of

this type would be naturally motivated to get as much out of it as possible since it satisfied a real need on their part, namely to learn to perform a task competently. There would be more to lose than to gain from trying to "fudge" or cheat when using this type of material.

Frame 2 is the separate "track" for those who indicate that they did not make the correct button insertion in Frame 1. It actually requires two responses, one the overt criterion behavior, namely pressing the Activate Button, and secondly, the requirement to write the word "activate." This was done to strengthen the association between the button and the term.

Frame 3 is both the end of the previous single track branch and the beginning of a multi-track branching sequence. Again, since light gun action has been mentioned at various times earlier in the program, this frame is fairly "dense." It simply reviews the main points connected with light gun action and asks the trainee to indicate the principle behavioral difference in terms of final activation between using the light gun and using the Activate Button. In other words, a trainee who understood that the track number is indeed not needed when the light gun is used, would have thus indicated that he grasped the essential difference between these two methods as far as button insertions are concerned. In this instance, there are two logical errors that could be made by those who did not correctly understand the relationship between the insertion of the track number and the use of the light gun. Both of these are thus listed in the alternatives. Each of them lead to a different corrective frame.

When used in this manner, the branching sequence is more diagnostic in correcting individual responses. Thus Frame 4 says more than simply "Your answer was wrong" but can say "Your answer, action buttons, was wrong" and cover in a remedial and review fashion the reason that particular response was inappropriate. The response term called for in Frame 4 is the same one that was called for in Frame 3, except that it is required that the subject write the response rather than simply point to it. As in other instances where branching is used, the overt-written response is considered to have greater retention value than the simple pointing response.

Subjects who respond to Frame 3 by pointing to "release buttons" are sent directly to Frame 5, thereby skipping, of course, Frame 4. Frame 5 is specifically aimed at correcting the misconception which was revealed by the specific response made in Frame 3. It contains more review material than does Frame 3 because it reflects a greater misconception of the relationship between the light gun and the insertion of the track number than the answer "action buttons." It might have been desirable actually to break this frame down into smaller steps, although this was not revealed in the pre-testing. Again the response called for is the same as that required in Frame 3, but in the overt-written format.

Frame 6 is not shown here but is the point at which all trainees return to the main track of the program.

Paired-associate format

In the earlier discussion of the organization of program materials (page 43) reference was made to the fact that some of the symbolic subject matter was treated in a format different from that used in the main body of the program. This format was identified with a type of symbolic material referred to earlier as being discrete in nature, i.e., having little internal referability (page 11). The decision to treat this type of symbolic material in a different manner was not taken until after a portion of it (the phonetic alphabet) had been put into a continuous-discourse format, utilizing the various programming techniques described previously in this report. The resulting program segment seemed to be overly long requiring a great many responses, not all of which were, on inspection, particularly relevant to the task. Since trial subjects learned the material well enough, it was not a question of adequacy, but efficiency. (Note the earlier discussion of this point on pages 53 and 54.)

Further, the self-instructional programs were obviously going to be long and there was other similar material yet to be programmed, e.g., the brevity code. (Not only was it desirable to keep the programs as short as possible, but valuable programmer time could be saved if a shorter format proved effective.) The experimental literature offered nothing specific in the way of data on

programming paired-associate materials. It was therefore decided to test some of these assumptions by developing shorter and simpler programs of various kinds, including a simple flash card format, and by administering them to trial subjects. Actually, six different programs were constructed covering the phonetic alphabet, three using conventional programming techniques and three using flash card techniques. Each of these is briefly described below.[1]

Program 1 -- Long constructed response program, overt responding, training time not limited. This was the original program as written for inclusion in the IND self-instructional materials. It was 90 frames long and the trainee responded overtly to each frame by writing the appropriate responses in the space provided.

Program 2 -- Short constructed response program, overt responding, training time not limited. This program consisted of 30 frames selected from the long program (Program 1).

Program 3 -- Short program, covert responding, training time not limited. The same short 30 frame program noted above (Program 2), except that trainees were instructed to simply think of the correct response rather than to actually write the response.

Program 4 -- Flash cards, covert responding, training time limited. This program was made up of flash cards consisting of a letter of the alphabet on the front and the response term on the back. The trainee was instructed to look at the letter of the alphabet which appeared on the front and try to remember its phonetic equivalent before looking at it on the other side of the card. (Trial one was a learning trial only; trials two and on were confirmation trials.)

[1] This study will only be briefly reviewed here. A complete documentation of the study is contained in: Shettel, H. H. & Lindley, R. H. An experimental comparison of two types of self-instructional programs for a SAGE system paired-associate task. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-TR-251 (AFCCDD-TN-61-20)

Program 5 -- Flash cards, covert responding, training time not limited. Program 5 differed from Program 4 only in the amount of time that the trainees practiced with the cards. This group was instructed to practice until they reached the criterion (self-judged) of two successive errorless trials.

Program 6 -- Flash cards, covert responding with drop-out item feature, training time limited. The trainees were told to sort their flash cards into two piles during learning, one containing the phonetic equivalents that they had anticipated correctly and one containing the equivalents they had not anticipated correctly. The trainees were then to practice with the pile of cards containing those items they had missed, repeating this procedure until the correct response was made to all items.

The data obtained from the administration of the six programs to 60 subjects and their subsequent testing revealed that flash cards can be an effective means of training discrete-item paired-associate material, especially when training time is considered as well as the amount of learning produced. The long constructed response program (1) was an effective instructional segment. It was, however, very inefficient (number right on test divided by training time). The covert response program (3) was slightly better than the overt response program (2) and it was a great deal more efficient as an instructional segment. As a matter of fact, considering efficiency alone, the short covert program surpassed all others. When absolute error rate is considered alone, however, it was not acceptable.[1]

[1] Efficiency scores can be misleading unless all subjects learn to the same level or unless the learning curves are linear. Program 3 was more efficient than the flash card group because, despite the relatively low level of achievement for this group, the level was reached in a short period of time. However, if it requires 20 minutes to teach 20 paired-associate items from the phonetic alphabet it does not necessarily follow that it requires only 26 minutes to teach 26 items, an assumption which is implicit in using number right divided by training time as an overall efficiency score. It may require less time, but since learning curves (particularly for paired-associate material) are generally negatively accelerated toward asymptote it would more often be the case that efficiency scores for low achievement groups would be spuriously high. Thus, Program 3, while having the highest efficiency score, was not effective enough to warrant its use, nor was it felt that its apparent efficiency would be maintained if it were modified so as to produce achievement levels comparable with those obtained with the flash card groups. When programming time is also considered in the overall equation (consisting in this case of time to learn, level of learning, and effort), there appears to be even less justification in recommending the "most efficient" program (Edwards, 1956).

Since all the flash card groups achieved high levels of mastery in this task, but especially those whose training time was scheduled (4 and 6), it was decided that a slight modification in presentation techniques would provide a suitable combination of high level criterion behavior in the trainees, short training time, and short programming time. This modification was simply to schedule the amount of time for drill in this material and, in addition, to reschedule a review period later on in the program. Thus, by referring to Table 2 on page 47 you will note that the phonetic alphabet and brevity code were scheduled at different points in the program with training times indicated.

The success of the flash card technique for the type of material described can be measured by the IND program test results. A naive group of four subjects (that is, those who had never been exposed to SAGE materials of any kind, including the phonetic alphabet) scored respectively 22, 26, 25, and 26 on a test requiring them to write all 26 items in the phonetic alphabet, for an average error rate of 1.3. This error rate is better than that obtained for the short covert and overt continuous-discourse programs reported in the study, even though that test was given immediately after the training period, while the IND program proficiency test was given after the trainees had completed the entire program. For many of them, this was a period of four or five days after they had received drill and review in the phonetic alphabet and also after the interpolation of a great deal of other symbolic material, e.g., the brevity code.

Distribution of response modes in each program

This section has described in some detail the large variety of techniques that were applied to the TM and IND self-instructional program. The relationship between one of the more important of these program variables, response mode, and the organizational structure of each program can be seen in Tables 4 and 5. These tables indicate the number and percentage of frames for each segment which were prepared in the overt-written response format and the number and percentage of frames prepared in the multiple choice, covert, and pointing formats discussed earlier. Table 4, which covers the IND program, also indicates the number of

branching frames included in each segment of the program.[1] (The TM program did not utilize branching.) The paired-associate segments have not been included in either of these tables since their position in the programs and method of responding has already been dealt with.

Table 4

Number and Percentage of Written and Other Responses and Branching Frames for each Segment of the Intercept Director Program

Program Segment Title	Overt-Written Responses N	%	Multiple Choice & Other Responses N	%	Total Frames	Branching Frames N	%
1 Introduction (SAGE)	43	47.2	48	52.8	91	5	5.5
2 Main Console	65	17.5	306	82.5	371	41	11.1
3 Wing Panels & Auxiliary Console	119	47.2	133	52.8	252	56	22.2
4 Outline of Mission	71	51.8	66	48.2	137	13	9.5
5 SID Symbology	62	19.4	257	80.6	319	9	2.8
6 Interceptor DID	93	40.4	137	59.6	230	23	10.0
7 Non-Interceptor DID	88	54.3	74	45.7	162	00	00.0
8 Interception DID	72	54.5	60	45.5	132	00	00.0
9 RTB DID	39	60.0	26	40.0	65	00	00.0
10 Standard Intercept Mission	287	41.9	398	58.1	685	16	2.3
TOTALS	939	38.4%	1505	61.6%	2444	163	6.7%

[1] The number of branching frames was computed as the difference between the minimum number of frames and the maximum number of frames it was possible to go through. Thus, in the example of branching given on page 56 ff., frames 1 and 3 would not be counted since everyone would be required to respond to these frames. Frames 2, 4, and 5 would, however, be counted as branching frames.

Table 5

Number and Percentage of Written and Other Forms of Responses for each Segment of the Track Monitor Program

Program Segment Title		Overt-Written Responses N	%	Multiple Choice & Other Responses N	%	Total Frames
1	Introduction	195	55.4	157	44.6	352
2	Track Problems and Actions	360	65.9	186	34.1	546
3	"Reference" Switches	81	55.9	64	44.1	145
4	Priority	68	54.0	58	46.0	126
5	Established and Non-Established Tracks	57	53.8	49	46.2	106
6	A, B, and E Characters	104	40.9	150	59.1	254
7	The Track Tote DID	108	62.4	65	37.6	173
	TOTALS	973	57.2%	729	42.8%	1702

It is interesting to relate the percentages in these tables to the subject matter covered in each of the segments. For example, Segment 2 of the IND program (Table 4) has only 17.5% write-in frames. This low percentage of write-in frames is due to the fact that this subject matter lends itself very well to pointing type responses. It is not important for terminal behavior that the trainee know how to write or spell terms such as SID, DID, Category Switches, Airbases, Boundaries and Landmarks, etc., nor that he can indicate on a verbal level that he understands the interaction of the Feature and Category Switches. These behaviors in their criterion form are essentially action behaviors, that is, the ability needed is to be able to locate switches and parts and to use them properly. Thus, a great deal of use was made of drawings on the frames themselves and of the

simulated console equipment which was part of the training complex.

The wide variation in the percentage of branching frames utilized in the various IND segments is largely a function of the rationale for their use. These sequences were used partly on the basis of program tryout but mostly on a subjective judgmental basis. A more systematic rationale for the use of branching would probably result in a more effective application of the technique.

It is interesting to note that the TM program (Table 5) utilized overt-written responses to a greater degree than did the IND program. This is another reflection of comments made earlier concerning some of the difficulty in properly explaining the nature of the duties of the TM. It takes a lot of descriptive material to explain track problems and actions. This is shown in the 65.9% figure for the number of written responses in the second segment. The teaching of symbology contained in the various DIDs is also a "wordy" subject. This is reflected in the Track Tote DID (62.4% written responses) in the TM program and in Segments 6, 7, 8, and 9 of the IND program (an average of 52.3% written responses).

IV. CONCLUDING REMARKS

A completely satisfactory self-instructional technology will not exist until a completely satisfactory science of human learning exists. Both areas will grow and develop together. The development and analysis of self-instructional programs, properly conceived, will contribute to the development of a satisfactory paradigm of human learning, and, as advances are made in the science of human learning, they, in turn, will contribute to the more rational construction of more adequate and effective self-instructional materials.

The programs described in this report contain a wide variety of programming techniques or "building blocks." Some of these blocks seem, upon reflection, to have been used because they "just seemed to fit," without being able to say why they seemed to fit. Others were selected on an a priori basis or plan. The experience of other program writers, experiments done in the area, and the common sense notions of the frame writer, all contributed to these "reasons" for using this or that block at a particular point in the program. And finally, even after selection, some blocks had to be changed and/or replaced because they could not hold up under trial stress.

The end result of this combined rational and trial and error effort was programs which seem to exhibit a certain logical structure and programs which seem to "work." Thus, to the extent that one can explain what was done and why it was done (methodologically) and to the extent that one can say that learning of a certain kind and extent was actually produced, then one can use the experience to add to the fund of knowledge that will, in turn, lead to programs with even better structures, built for even better reasons, and producing even better results.

How well the programs under discussion did, in fact, "work" is covered in detail in another report (ESD-TN-61-51). In general, test scores for all groups revealed a high level of learning, averaging 83%. Subjects in the naive IND group (who knew absolutely nothing about SAGE before training) averaged 71.9%

on a test covering basic job knowledge after an average of only 26 hours of instruction with the IND program. Personnel with an average of 13 months of on-the-job SAGE experience as INDs but who did not go through the program, scored 84.3% on the same test. Similarly, the naive TM group scored 80.7% on a proficiency test after 16½ hours of instruction. Experienced TMs who averaged 18.8 months on-the-job scored 78.8% on the same test.

These may be an impressive combination of figures under ordinary circumstances, but an applied science of learning demands more of its practitioners than "71.9% learning." It has a right to ask about the other 28.1%. (Note that the test covered only what was specifically "taught" in the program. There were no tricks used; the trainee simply had to be able to emit in essentially the same format and in essay form, the material taught in the program.) Why was certain material not learned? Indeed, why was the other material learned?

It was not within the scope of this work to make an analysis of each subject's responses to each individual frame in each program. This would be possible, in any case, only for the overt-constructed written responses. (A sampling of these written responses was analyzed and is discussed in the report noted above dealing with an evaluation of program results.) For other kinds of responses (pointing, covert, etc.) only the total number of errors made by a subject was recorded. (Note that equipment used interacts with the analysis of programs as well as with the presentation of programs.) On a general level the sample analysis showed that the number of written errors made during the program is correlated (a rho of +.55) with the score obtained on the criterion test. But there were exceptions. Some trainees who scored highest on the test also made the greatest number of errors during the program. Do some people learn (better) while making errors (which are immediately corrected)? If the programs were "better" for some, would they be "worse" for others? Can branching, or indeed should branching, try to account for these kinds of subject variables?

Approach to self-instructional research -- experimental and applied

These questions, and many more, could be asked at present only rhetorically. There are no final, or even satisfactory, answers. The position taken in this report is that answers will be supplied only as programming (both in its experimental and applied phase) is approached as an applied science of human learning behavior. Thus, to satisfy this condition, programming efforts should include (1) a behavioral analysis of the subject matter, (2) selection and application of programming variables on the basis of stated hypotheses that relate them to the behaviors covered, (3) empirical tryout using criterion behavior as a measure of effectiveness, (4) analysis of the program to determine specific weaknesses and to test hypotheses made in 2, and (5) revision of methods, procedures and hypotheses in 1 and 2 above on the basis of this analysis. (Obviously, this approach is not possible for all programs. Most of those who produce programs only want to apply the technology, not develop it. In this connection a handbook was prepared under this contract to assist Air Force training personnel in the application of programming techniques and principles to the development of self-instructional training programs for SAGE and similar L-system tasks.)[1]

However halting the steps may be, this approach is suggested to provide for maximum payoff from both the experimental and applied-experimental fields. The companion areas of film and television research have been, and are still, plagued by such questions as "Is a color film a better teacher than a black and white film?" or "Can television teach second semester French?". Asking whether overt responding is better than covert responding, or whether branching programs are better than nonbranching programs, will produce gains in knowledge of human learning and self-instructional methodology only to the extent that the unstated, but very broad, assumptions are in fact true, i.e., that there is indeed a one best way of responding and that the influence of branching is not a function of subject matter skills and behaviors and/or learner variables.

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[1] Shettel, H. H., Angell, D. & Lumsdaine, A. A. Handbook for the preparation of self-instructional materials for SAGE operators. Pittsburgh: American Institute for Research, 1961. AIR-C11-61-SR-248 (AFCCDD-TN-61-30)

Thus, the present programs used experimental studies in the literature (and conducted one study to test a programming-subject matter interaction that had particular relevance for paired-associate material of a specific kind), to help decide what kind of program to write, not for all of the complex TM or IND subject matter, but for individual skills and behaviors contained in each of them.

Specific program inadequacies

The two programs under discussion obviously fell short of meeting all of the goals set forth. In addition to reflecting the general inadequacies of the state of the art, as discussed above, specific program inadequacies were revealed as a result of the field trials. This report will conclude with a discussion of the various ways in which it is felt that the TM and IND programs, and similar programs produced in the future, could be made even more effective.

1. Organization of program materials.

Attention to the organizational structure of both programs seemed to be inversely related to the level of organization. Thus, considerable time was devoted (and properly so) to the overall structure of the programs as reflected in Tables 1 and 2. A good deal of attention was also given to the general organization of segments. However, the organization of frames dealing with individual subject matter units was not given adequate attention. It is true, of course, that the empirical tryout of programs tends to correct for errors made in the smaller units of organization while not generally providing information as to the adequacy of the larger structure of the program. Nevertheless, it is believed that more attention to the build-up of individual subject matter areas would result in a better overall program organization.

Helpful in this connection would be the itemization before the program is written, of each response believed to be important in the building of a particular skill in the order considered initially appropriate.[1] After the segment is written,

[1] The primary sources of terms and concepts used in the TM and IND programs were two source documents developed by the project staff from a review of existing training literature, interviews with operational personnel, and on-the-site observation of the tasks. These documents are discussed and excerpted in, and attached as separately bound appendices to, ESD-TN-61-52. They are available for limited distribution only.

the responses actually used and the strength of the prompt used to elicit them are itemized. (Where various response modes are used, the mode of response would also be usefully indicated.) The initial list is then compared with the final list. Overemphasis, underemphasis, and, of course, omitted items will thus be revealed. This approach was utilized in two instances on a systematic basis and was otherwise less systematically followed in both programs. In one instance (the Non-Interceptor Track DID segment), a simple scatter plot was made, with the frame numbers on the ordinate and the symbols used in that DID on the abscissa. A sample from the resulting plot is shown in Figure 4.

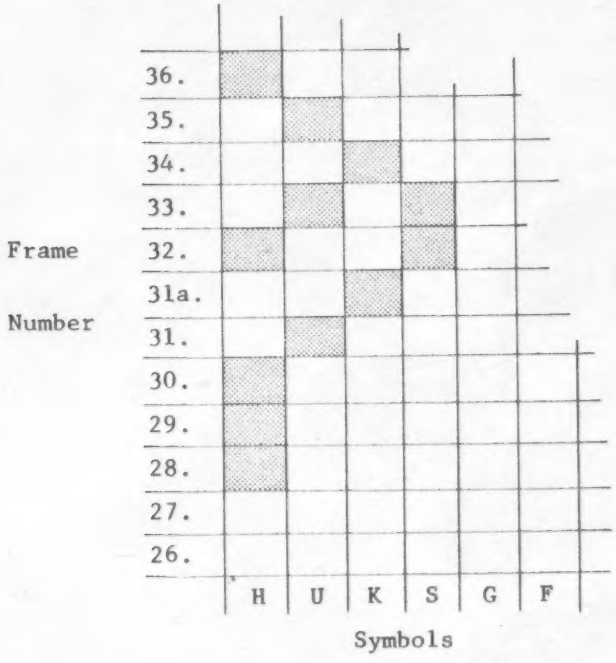

Fig. 4. Excerpt from simple program analysis form.

This figure shows the pattern of responses for each symbol and would indicate any gaps, or the lack of sufficient review (assuming the programmer knew how much review was sufficient).

A slightly more complex scheme was used for one version of the phonetic alphabet segment, a sample of which is shown in Figure 5.

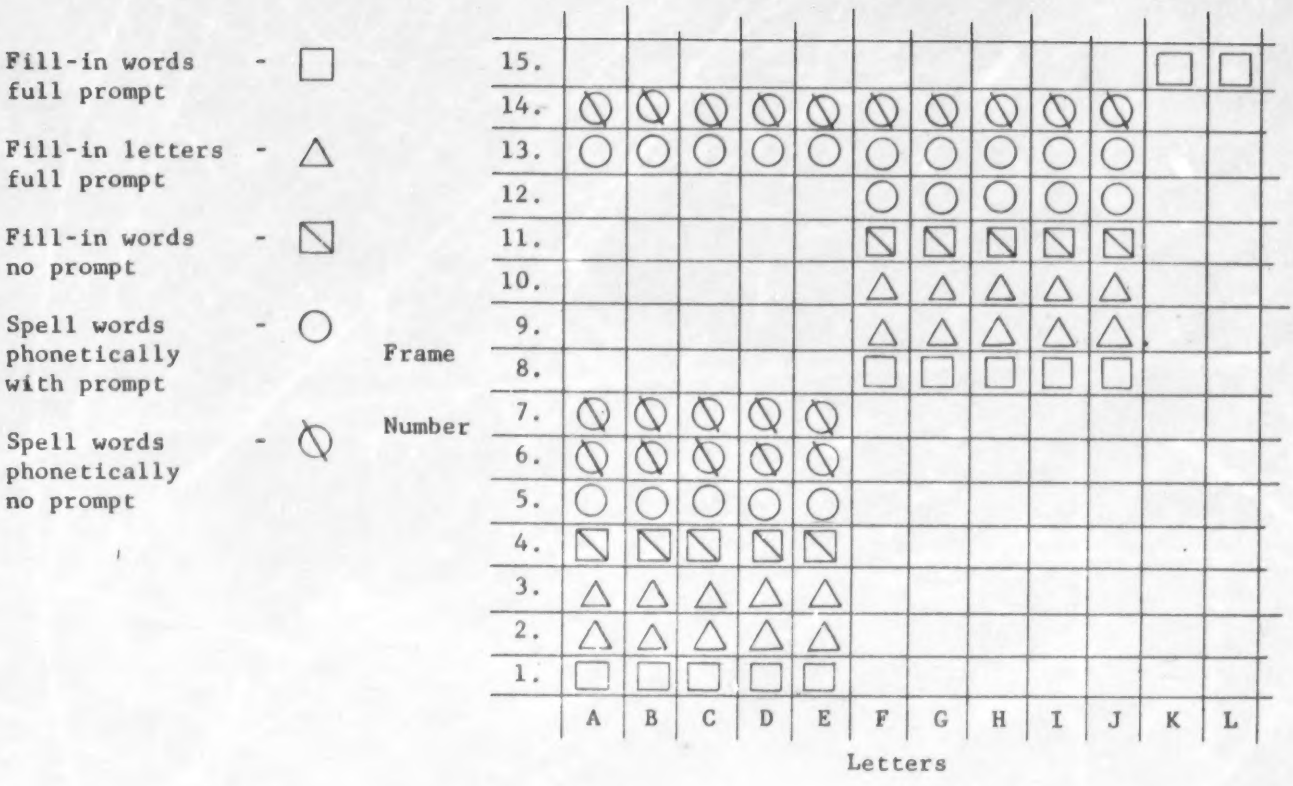

Fig. 5. Excerpt from more complex program analysis form.

The type of form shown in Figure 5 makes it possible to analyze the form of response made as well as where and how often it is made. Further codification would result in even greater diagnostic insights into the program. Unfortunately there is, as yet, no adequate taxonomy for cue strength, size of step, etc. (Gilbert for one, has categorized frames functionally, i.e., lead-in frames, interlocking frames, etc.)

2. Branching.

The application of branching on the segment level appears desirable as a result of the field trials. As previously noted, these self-instructional programs were developed primarily for the naive trainee. Field trials, however, included subjects who had various degrees of SAGE experience. Parts of both programs would

be considered common knowledge to anyone who had been through a SAGE training school or who had spent a few months in a Direction Center. These portions of the program could have been dropped out by developing a pre-test which would indicate the skill entry level of the trainee.

In one instance, an effort was made to compensate for the lack of segment branching. It was clear that Direction Center personnel were already familiar with some portions of the material. It was therefore decided to omit one of the segments, but solely on the basis of their verbally reported background experience with the subject matter. This was done for the phonetic alphabet segment in the IND program. Men who indicated that they knew the phonetic alphabet were allowed to skip this paired-associate (flash card) material. (It is interesting to note, however, that the group who was thus allowed to by-pass this segment made the most errors in that part of the IND proficiency test which covered the phonetic alphabet. Verbal reports of knowledge and skills are obviously not a substitute for more reliable indices.)

The overall organization of materials could have been arranged in a manner which would have allowed segment branching to be more easily accomplished. The introductory material, for example, that led the naive subject into the discussion of the IND or TM positions, could have been omitted from the programs when they were utilized with SAGE (nonnaive) personnel had this material been separated out from the main body of the segment of which they were a part.

A more heterogeneous group of subjects for use in the preliminary tryout of segments and portions of segments would have revealed in a more diagnostic fashion the need for additional branching sequences. Poorer trainees would indicate where remedial work would be needed; better trainees (some with SAGE experience) would have indicated where branches could allow the by-pass of some material. In the present instance only naive subjects were used for program tryout purposes.

3. Review sequences.

A good deal of the material taught in both programs was contextually

reviewed simply as a result of the natural development of the subject matter. The logical interrelationship and interdependency of some skills accounted for this type of internal review. However, other skills were not so related and tended to drop to a low level of performance by the time the program was completed. Additional review of these materials would have been helpful.

This is particularly true of the DID program segments. They taught a large amount of symbology, all of which could not be used during the remaining portions of the program. Material in these DIDs which was not used suffered from retroactive inhibition as other material of a similar nature was superimposed on it.

This problem could also be approached by re-entry into earlier portions of the program on the basis of criterion response questions. Thus trainees would be tested on DID symbology later in the program. If they scored below a certain point they would be returned to the earlier segment covering that material. This would make it even more desirable that these segments contain considerable branching since trainees would be entering the segment with different levels of proficiency and would require varying amounts of additional instructional material. Such techniques would add to the administrative burden but the equipment used in this program would have made it possible (mechanically) to operate in this fashion.

4. Responses and cues.

Selection of relevant responses was, in general, carefully attended to. However, some frames can still be found that show poor selection for the response term. In other cases, response strengths were built up to a high level but allowed to diminish through disuse for the remainder of the program. (This has been referred to above. For the tapes analyzed, written response errors averaged less than 5% for both programs.)

Analysis of the write-in tapes also revealed some peculiar transfer of responses even though the pre-testing of the program did not reveal such errors. Thus the following frame seems to be a perfectly good one, with adequate internal cues, when considered by itself.

A center at which one of these high speed computers is located is called a Direction Center, which is abbreviated DC. Radar information from ground, air, and sea sources and nonradar information, such as flight plans, are fed into these [ ] [ ].

Direction Centers

Most subjects responded to the above frame with such terms as "high speed computers," "electronic computers," etc. The reason for this is simply that the previous five or six frames discussed, in some detail, the computer and the fact that data of the type mentioned in this frame was fed into this computer. Despite the internal prompts of this frame, the earlier response strengths and the lack of adequate preparation led to the wrong response. While the subject matter in this case is not vital to criterion performance, it is distressing to the trainee to be told he was wrong when the response he made seemed a perfectly reasonable one to him.

Efforts to weed out frames which were either inadequately cued or over-cued were fairly successful. However, some frames remain which exhibit these traits. For trainees who had some familiarity with SAGE, it is probably the case that the general level of cues is too high, resulting in responses that are too easy to make. This is, of course, closely related to the problem of branching. While branching cannot directly influence the strength of a cue within a frame, it can influence the repertory which the trainee brings to that frame, and thus the contextual cue strength of that frame.

The general guidance with respect to cue strength which was discussed

earlier, namely, to get the subject to elicit the response with assured correctness with the minimum cue necessary, was, of course, only approximated due to the lack of a technique for adequately measuring response strength at any given point in the program. Transferring the control of responses from prompted training stimuli to unprompted criterion stimuli is a delicate problem. Perhaps as difficult as anything in developing these programs was keeping the frames interesting and challenging at the same time that the frames produced learning and contained cues of adequate strength.

5. Program tryout.

As indicated above in the discussion of branching, a larger number of trycut subjects exhibiting a wider variety of skills and aptitudes in the areas covered by these programs would have been desirable. This approach would result in more diagnostic branching sequences and better control over the shaping of desired responses. It should be repeated, however, that program tryout, at its best, can only lead to what will work, not what will optimally teach the material. Only a rational, not empirical, approach can do that.

The accumulative effect of the entire program is not revealed in a segment by segment tryout. This is not critical with small programs, but the length of the programs under discussion was such that response degradation of some material became a factor, partly through the effects of retroactive inhibition as noted earlier. Conversely, and of equal importance, there is possibly a positive effect in the logical build up of the subject matter when learned "in toto." This would facilitate learning and could lead to a thinning of the final program to achieve optimal results.

Some modification in the IND program was made as a result of an initial full-scale tryout with naive subjects, but time constraints did not allow a careful analysis of individual responses of these subjects and thus only a first approximation of an improved program could be made. Subsequent experience with the programs during the field trials revealed that, while both programs taught a great deal of material in relatively short periods of time, additional opportunities for revision would have resulted in even more effective programs.

To conclude these afterthoughts, the experience gained in the development and use of these two programs reinforced the notion that the utilization of a variety of self-instructional programming techniques in a single program was desirable and effective. As has been noted, such an approach does present problems in selecting from the available repertory of techniques those most suitable for individual subject matters and frames, but as the art of programming becomes more of a science, the reasons for using the various available techniques will be more carefully delineated. There is every reason to believe that a topology of programming will be developed which will relate the various behavioral and skill areas to the self-instructional techniques available. This report has suggested, tenuously to be sure, some of these relationships and could be considered a heuristic exercise in the area.

The integration of programming methodology and its equipment (teaching machines) with various kinds of ancillary training equipment, such as a simulation of the work station at which the trainees will perform after the instructional program has been completed, was also shown to be both feasible and highly desirable. The present programs, without the inexpensive, functionally simulated IND and TM console mock-ups, with their simulated flashing situation displays, would be a good deal less effective in building toward and transferring to criterion job behavior in the trainee. In the future, indeed, the self-instructional materials for certain tasks may be presented at the actual work station utilizing, in the case of L-systems such as SAGE, the display and readout characteristics of the operator's console to present portions of, or even all of, the program.

As more is learned about the interaction of subject matter variables and human learning variables with programming variables, the application of computer inputs to self-instructional methodology will become more important (Pask, 1960). Already being seriously considered and experimentally tested is the application of computers to provide for the more flexible presentation of programs, allowing branching to be more carefully controlled on the basis of the trainee's cumulative performance record as he progresses through the program. (This approach could have made a significant contribution to the effectiveness of the TM and IND

programs discussed in this report.) The coincident development of a programming topology and a functional codification of human behaviors and skills will make it possible to use computers not only to present programs, but to assist in the analysis of, and, indeed, the very development of, self-instructional materials.

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